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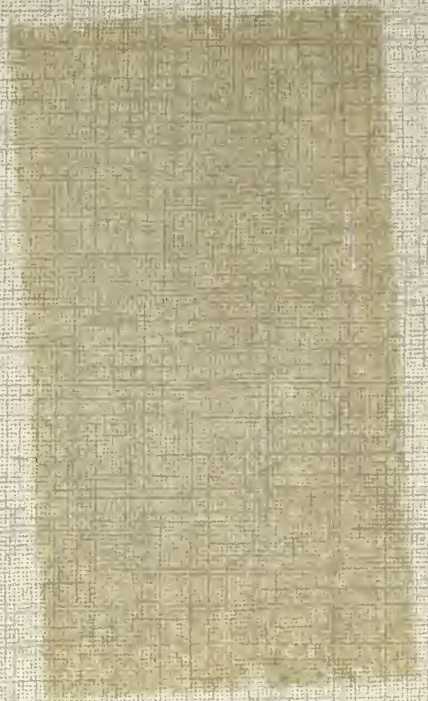

ENVIRONMENTAL MONOGRAPH NO. 1

Vulnerability, Resilience and the Collapse of Society

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VULNERABILITY, RESILIENCE AND THE COLLAPSE OF SOCIETY
A Review of Models and Possible Climatic Applications

Peter Timmerman

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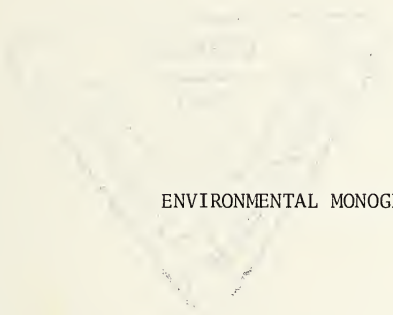

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PREFACE

The impetus for this paper came from two sources. First, the concern for the development of a competent social component in the World Climate Program being undertaken by the World Meteorological Organization led to the following declaration by the World Climate Conference of one main objective of their Impact Study Program:

> Determining the characteristics of human societies at different levels of development and in different natural environments which make them either *specially vulnerable or specially resilient* to climatic variability and change and which also permit them to take advantage of the opportunities posed by such changes (WMO 1980).

Admirable as this objective is, it is difficult not to see it as partaking in the general vagueness which attends much of climatic impact assessment at the present time, and which has been admirably described by Kates (1980):

> The underlying assumptions of models are poorly defined. Studies with widely varying subject matter are characterized under a common rubric of impact study. Techniques are poorly developed methodologically and are weakly integrated beyond the discipline in which they were first initiated.

For example, it is hard to say just what "vulnerability" and "resilience" are.

One source of this paper, then, was a concern that some of the concepts coming to the forefront in the fast growing subject of climatic impact assessment were under-examined. Some discussion of terms, concepts, and models - those often unconscious shapers of research frameworks - seemed advisable. Munn (1979) makes the distinction between a *climate impact assessment* and a *climate impact study*, of which the first is a policy-shaping document, and the second a research or applied study. It is worth taking steps to ensure that we are not falling between both these categories, and are instead about to embark on policy disguised as research.

The second source for this paper was the particular concern of the Atmospheric Environment Service (Environment Canada) that the Canadian Climate Program should be as effective as possible. Atmospheric Environment has a long and enlightened tradition of concern for climatic impacts and the welfare of the users of the meteorological information it provides. To this end, it has provided funding for projects at the Institute for Environmental Studies and elsewhere which attempt to bridge the gap between the technical and the social use of climatic information. In the present instance, it will be noted that, apart from a predominance of references to instances of climatic resilience and vulnerability, and the discussion in the last section of this paper, there is little here of direct or immediate relevance to the daily requirements of AES. On the one hand, one could ascribe this to the typical result of much of social science (to the despair of the "hard" scientist), which inevitably concludes that the problem is itself problematic; on the other, it could be that what is presented here is only one part of an immensely difficult attempt to say anything worthwhile about the relationship between climate and society - the charting of the interactions between a system indeterminate through sheer complexity, and a system indeterminate through sheer complexity and sheer humanity.

In any case, it is hoped that this paper will be of some use - if only of a exemplary nature - in the further development of the Canadian Climate Program. My thanks go to AES for their support of this research; and to Professor Munn who believed it would be worthwhile; and to Professors Burton and Whyte of the Institute for Environmental Studies for their assistance. Also to Miss J. Retèl, who probably thought it would never come to an end.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
1. The "vulnerable" society	1
2. Basic models	3
Model 1. The moral model	4
Model 2. The functional-organic model	6
Model 2a. Optimism	6
Model 2b. Pessimism	7
Modified Model 2.	8
Model 3. The limit model	12
Model 4. The systems model	14
VULNERABILITY	17
RESILIENCE	19
DEALING WITH UNCERTAINTY	22
I. Stress	26
II. Adjustment and adaptation	26
III. Impacts	29
RESILIENCE *versus* RELIABILITY	31
CLIMATIC IMPACT ASSESSMENT	33
CONCLUSIONS	38
REFERENCES	39

INTRODUCTION

1. THE "VULNERABLE" SOCIETY

Not since Oswald Spengler first introduced the phrase "the decline of the West" into the common vocabulary after the First World War has the proposition that the Western world is on the verge of collapse or, at the very least, decline commanded such sway. Below the apocalypse of nuclear war, there is a widespread sense of possible catastrophe, of the toppling of social order through disaster, resource depletion, sabotage, or the embargo of vital supplies. Along with this has come a growing concern for the vulnerability of modern complex societies to both instantaneous and long-term assault; and this concern has been translated into calls for the building of "buffering capacity" or resilience into our socioeconomic system. Self-sufficiency, stockpiling, lifeboat ethics - like the citizenry of the Dark Ages, we are moving back into castles, and awaiting the onslaught of the Vikings. Enemies are all around us. At one end of the scale, the enemies are human: the new barbarians of varying hues and persuasions; at the other end, the enemy is Nature: the known and unknown response of Nature to what is being done to her, mingled with her own autonomous powers of destruction.

At bottom, many of these concerns resolve themselves into a concern for the preservation of stability, whether it be the stability of the *status quo* or the stability of reasonably assured growth in a healthy society. Three events may be said to characterize - though not to define uniquely - the basis for these widespread concerns.

The first was the Vietnam War, which for some represented the high-water mark of American pre-eminence in the world. For many more, the humiliation of that experience constituted the removal of a basic assumption of unexercised but ever-available supervision of world order. Once that underlying assumption of power was called into question, the world order began to be seen as an ordered system, and not just as the inevitable result of the modern equivalent of Adam Smith's "invisible hand":

> For it is fairly clear that the world system created after the Second World War is breaking down. This system, conceived under the banner of "interdependence" and symbolized by an institutional panoply (the International Monetary Fund, the World Bank, etc.) of impeccable Western rationality, was based on a belief in the efficacy of a combination of political democracy and industrial efficiency ... This faith was accompanied by a dynamic and melioristic rationalism which held that the world's political and economic problems could be solved by international cooperation and the application of solutions based on Western technology and economic organization. ... and the same image still lurks like a beneficent phantom behind the efforts of statesmen to cope with growing chaos. (Hartley 1980).

The second event, following closely on the end of the Vietnam War, was the series of climate related disasters in 1972 and 1973. The drought in the Sahel, the failure of the Peruvian anchovy harvest, the bad Soviet grain harvest and the subsequent massive disruptions of the commodity markets - all these drew attention to the interdependence of the ecomonic system. In this case, stress at a point half a world away was felt at the heart of the system. Moreover, the events suggested that there was very little true spare capacity in the world system, and that something as unpredictable as climate could conceivably have major impacts on a world living at the limit. As the world became a global community, it also realised that it had become a marginal community. In fact, it could be suggested that the questioning of the continued benevolence of the socioeconomic system was almost instantly followed by a questioning of the continued benevolence of the climatic system of the previous half-century.

The third event, which did for energy what the Sahel did for food, was the Arab oil embargo of 1973-1974. First, and most obviously, the embargo showed the increasing dependence of the Western world on insecure supplies of one strategic

commodity. Second, and not quite so obviously, the embargo showed that the maintenance of a modern society in the present conditions of declared "peacetime" demands that the conditions of trade be secure and reliable and - perhaps most importantly - accepted. In the twentieth century, we have come to recognize that modern war is basically a function of the mobilization of the full resources of society; which means that we no longer necessarily "gear up" for war - indeed, nuclear war is so swift that we must be geared up before we start. As a result, it is very difficult to separate what is economic attack, and what is "war by proxy". For terrorists, of course, the *status quo* of the society they wish to attack is oppressive and a target by definition. What the oil embargo brought into the forefront was the possibility of institutional terrorism, or the use of the world economic interdependence as a weapon of war. In the absence of security and reliability, and in the absence of the "declared war", which gives *force majeure* assurance of regularity of supply, the withdrawal, manipulation, or disruption of markets brings a dependent society face-to-face with the vast array of components of the day-to-day system which are "vulnerable". A strategic analyst would make the obvious point that it is only when you go on the defensive that you discover weaknesses in what used to be strengths.

At its best, the embargo provoked necessary analyses of some of the strategic resources and their misallocation (Darmstader *et al.* 1977; Stobaugh and Yergin 1979) by industrial societies; and suggested that alternative scenarios for future activities might produce greater resilience in the face of international stoppages. At its worst, the embargo has had the result of stimulating the emergence of a "garrison state" mentality, which seeks to replace the confidence in the relative efficiency of market trade with a confidence in the expensive and potentially wasteful maintenance of high inventories of strategic goods.

What cannot be emphasized enough, however, is the resultant view of society as engaged in the peacetime equivalent of defence from attack. This requires an analysis of the ways in which society is "vulnerable" or "resilient" in the face of onslaught or crisis, whether the attack is man-made or natural. And under the unusual conditions outlined above, it is extraordinarily difficult to control the analysis, since everything from moral fibre to the alignment of the planets is theoretically allowable - since what we are talking about is, fundamentally, our entire way of life.

One attempt to focus on the whole complex notion of the "vulnerable" society has been in the field of impact assessment, particularly climatic impact assessment. This will be examined in some detail later in this paper, but in light of what has been said, it can serve as a brief example of the kind of work this notion is beginning to create:

> A society is likely to "bounce-back" more effectively if it has accumulated stocks or reserves; if it has spare capacity built into the design of its infrastructure; if it has great command of resources, transportation, technology, and accumulated wealth with which to combat the impact (SCOPE Workshop on Climate/ Society Interface 1978).

Or:

> For instance, is society any more vulnerable now to climatic change than in the past? What sectors of society are really most vulnerable? Can anything be done to reduce risks associated with climatic variability? (Schneider and Temkin 1978).

Recently, these concepts have become enshrined in the objectives for the Impact Study Programme within the World Climate Programme, one of which was:

> Determining the characteristics of human societies at different levels of development and in different natural environments which make them either *specially vulnerable or specially resilient* to climatic variability and change and which also permit them to take advantage of the opportunities posed by such changes (WMO 1980).

Preliminary studies aimed at meeting this objective are underway (Warrick 1980; Kates 1980; Warrick and Riebsame 1980). Some initial hypotheses have emerged: rapidly developing countries are more vulnerable than developed countries (Burton *et al.* 1978); persistent and adaptive societies, through their technology and social organization, lessen climatic impacts of recurrent events of similar magnitude; success in lessening comes from increasingly elaborate buffers which are themselves responsible for possible catastrophes of lesser frequency (Climate and Society Research Group 1979).

As a general result of all of the above, and of other factors, the terms "vulnerability" and "resilience" have come into use as important indicators (some would prefer "buzz words") of a broad conceptual framework now being brought into play, not just in the nascent discipline of climatic impact assessment or socio-climatology, but in many other fields as well. Nevertheless, although they are obviously terms with great latent explanatory significance - their usefulness for ecological theory attests to that significance - no real clarification of these terms exists.

In response, this paper attempts to explore the use of the two concepts - "vulnerability" and "resilience" - which are coming into more and more frequent use in the analysis of the general characteristics of socioeconomic systems.

It is contended that three considerations make what follows both useful and necessary.

First, "vulnerability" and "resilience" are moving from being terms of secondary or tertiary rhetorical rank to the position of ultimate terms, sanctioned and sanctioning in times of crisis.

Second, "vulnerability" and "resilience" bring with them a curiously fascinating and superficially compelling amalgam of social and ecological models, deriving power in part from mostly unexamined models of social collapse, and in part from analogies with technical descriptions in ecosystem management (themselves oddly derivative from mechanics).

Third, "vulnerability" and "resilience" are rapidly finding their way into proclaimed guidelines for future research in areas such as energy futures, risk management, and climatic impact assessment.

In the course of researching for this paper, it became clear that the second consideration was perhaps the most important of all, since the use of the terms connoted differing views of the abilities of socioeconomic systems to deal with extraordinary stresses. Not only were these views held unconsciously or unexamined, but contradictory views were held simultaneously.

At the same time something of a slow development could be identified, a modification to take into account increasing social complexities and anomalies, which suggested that "vulnerability" and "resilience" were not the starting point for discussion, but as much as anything the natural development of both the historic concerns outlined above and modern social science research.

2. BASIC MODELS

We should like to begin the review by sketching out some basic models or paradigms of social systems under stress. A critical analysis of this kind involves the articulation of paradigms or models derived from the assumed, incoherent, or unexpressed paradigms within which theories of social change have operated. The worth of this is outlined in Parsons (1951):

> The paradigm primarily accomplishes two things. First, it serves to mobilize such knowledge of laws as we have in terms of its relevance to the problems of the explanation of processes *in the social system*. Secondly, it gives us canons for the significant statement of problems for research so that knowledge of laws can

> be extended ... a paradigm is a set of canons for the statement of problems in such terms as to ensure that the answers to the questions asked will prove to be of generalized significance, because they will state or imply definite relations between the fundamental variables of a system.

This is, in a sense, the ultimate goal of description: the creation of a new paradigm which makes better sense of the world than the previous paradigms. That is not what is presented here. What is presented here is a description of the competing models of social complexity and social collapse in order to assist in the formulation of new methods of approach to the questions involved. Before one can see, it is necessary to clean one's glasses.

Taking as our starting point Harvey's (1969) definition of a model as "a temporary device to represent what we think the structure may, or ought to be", we may begin by asserting that there are a number of working models, "temporary devices", or even standard myths concerning the ability of a complex modern society to withstand extraordinary stresses to its integrity as a system. As Harvey's informal definition indicates, it is difficult to separate "may" and "ought" from these models - the descriptive is often disguised prescriptive. In the same way, it is doubtful if anyone subscribes to a pure version of these models as presented below. Rather, we can consider them as "ideal types" in the Weberian sense (i.e. idealized for the purposes of clarification and exposition).

Four of these models of possible social collapse - with variations, interpenetrations, and elaborations - command most support.

Model 1 is the moral model, which says that the rises and falls of societies are mirrors of the goodness or corruption of the people in them. Model 2 is the functional-organic model, which uses analogies from mechanics and organisms to describe the functioning of society. Model 3 is the model of limits. Model 4 seeks to apply some of the insights of systems theory to society in a systems model.

Each of these models has a history, in some cases spanning the history of human thought. If put in a rough order, they chart a particular course through the various attempts to understand society in action.

Model 1: THE MORAL MODEL

The moral model has the longest history, and is by no means dead yet. As recently as 1971, the President of the United States invoked it explicity when describing the present state of his nation:

> I think of what happened to Greece and Rome, and you can see what is left - only the pillars. What has happened, of course, is that the great civilizations of the past, as they have become wealthy, as they have lost their will to live, to improve, they have become subject to the decadence that eventually destroys the civilization. The United States is now reaching that period. (cited in Galtung *et al.* 1979).

Degeneration through excess wealth, through loss of the will to live, through moral decadence: all the major themes are here.

The source of this model - or one source - can be found in the source of all modern political and social theory, the historians and philosophers of Ancient Greece.

For Thucydides, the decline of Athens was initiated by a moral degeneracy brought about, in the first instance, by the devastation of a great plague. For Aristotle, in "The Politics", the state that survives is one that matches its temperate size with the moral temperance of its citizenry: civic collapse is the result of factional strife based on inequality. And, in general,

> All political writings, in Greek civilization, deal only with virtues; their presence or absence is the only reason for the rise and fall of states (de Romilly 1977).

The question of the rise and fall of states, however, was dealt with only peripherally, or at the most general level. Possible causes of social collapse were not articulated at all clearly - one reason being the essentially static nature of Greek thought (Spengler 1918), another being the one-directional nature of the organizational change that was posited, namely the necessary movement of the *polis* towards the fulfillment of moral ends.

Considering its subsequent history, pagan Rome has ironically little or nothing to say about decline and fall, except for platitudes about the superiority of the rustic Golden Age of the past as compared with the squalor and degeneracy of contemporary urban Rome. The first full-blown moral model of Rome's decline appears in St. Augustine's "City of God", written to deflect criticism that it was the degeneracy of Christianity which sapped the vital strength of Rome. Augustine's reply was the assertion of the inevitable destruction of the earthly city as the preparation for the City of God, or at least as its counterpoint. Augustine's model was a Christian version of the moral code of the Hebrews as expounded in the Old Testament. The Hebrew model forecasts the destruction of the community of Israel when it strays from God; the Christian model assimilates that idea, and extends it to the individual soul. In this way, individual, community, sovereign, and deity become integral parts of a great hierarchy in and through which the blame for degeneration can be assigned to any level below God.

Of course, to the medieval world which lived by this model, the collapse of society was purely secondary: it was the salvation of the individual soul that was at stake. It was only when the Renaissance turned its attention to the salvation of man *in society*, i.e. man as a political animal as well as a spiritual being, that the implications of the possible collapse of society through the collapse of the underpinnings of the great hierarchy came into prominence. The most familiar, classic, examples of this concern are in the dramatic plays of Shakespeare, where, like Chinese Emperors struggling for the all-justifying "Mandate of Heaven" (another moral model), the ups and downs of royalty are echoed in the reverberations of a troubled universe.

It was Machiavelli who initiated the next stage in the process, since to him the salvation of society was perhaps even more important than the salvation of the individual - hence the use of religion as an acceptable propaganda weapon in the armoury of princes. Transferred from the troubled world of the Italian city-states to the troubled world of the English Civil War, Machiavelli's secular concern for survival found its counterpart in the rigidly materialistic social philosophy of Hobbes, who introduced the notion of the Social Contract into political discourse. This supremely influential moral model was based (in Hobbes' version) on the ultimate sanction of survival, pure and simple: not only was society constructed to eliminate the struggle of individual against individual, but if, at any point, the sovereign power was unable to protect the individual, allegiance to it was dissolved. Haunted by the depredations of the Civil War, Hobbes and the later English political philosophers were not primarily concerned with the causes of dissolution; rather, they were concerned with the preservation and justification of the existing society (Macpherson 1962).

In any case, the fundamental question has been posed: if societies were in some sense self-generating, why were they not self-perpetuating? This was the impetus for the study of the decline and fall of Rome, a study which begins with Montesquieu in the early eighteenth century, and receives its apotheosis with Gibbon towards the end of the century. Over-extension, fragile over-sophistication, moral decadence - these themes occur and re-occur down to the present. This went along with a new theme, the sheer complexity of society itself, a theme which becomes inescapably linked to the long series of moral questions sketched out above. The first two contestants over the value of complexity in society were Edmund Burke and Jean-Jacques Rousseau.

For Burke, the complexity of society, with its traditions and vast network of interdependencies, was a "given" that could only be taken away at immense cost to the well-being of society. In fact, replacement of that richness by some abstract scheme was a short road to anarchy or tyranny. For Rousseau, social complexity was a condition of mutual slavery, mutual incomprehension, and artificiality. The alienation of people was due to interdependence, and not - as Burke might think - from lack of ties (Wilson 1975). In a real sense, this disagreement as to the goodness or badness of social complexity is at the heart of every other model we shall be discussing.

One last example of the moral model should be mentioned, although there are those who would suggest that it is a scientific model, namely the Marxist model. It is something of a commonplace that Marxism can be considered as one of the substitute theologies that rushed into the vacuum created by the "death of Christianity" in the nineteenth century (Steiner 1974). Yoking together the claim for scientific validity and the power of an apocalyptic millenarianism, Marxism is a critique of capitalism and its crises. Indeed, one of the major points put forward by Marxists against capitalist theorizing is that there is a deliberate avoidance in capitalist theory of possible social collapse or the crises of capitalism (at least until recently).

The most interesting development of Marxism for our purposes has been the number of attempts to deal with the obvious fact that the theoretical predictions of Marxism keep not happening in the real world. One result has been the formation of a school of analysis devoted to "late capitalism", which shifts the emphasis from economic theories of capital accumulation to psychological theories of the necessity for altering the consciousness of the workers. The growing number of crises of capitalism begins to "raise the consciousness" of the worker, who must recognize the nature of the regime in which he lives before he can even want to overthrow it. Ultimately, of course, this is a variation on the theme of moral degeneracy. Capitalism loses its moral force, its moral glue, by undergoing a "legitimacy crisis" which undermines the normative basis of the whole system (Habermas 1973). Another version of the same problem, outlined by Rosa Luxemburg early in this century, is the coming up of capitalism against limits to growth. The vital engine of infinite economic growth smashes up against the wall of finite resources (Rousseas 1979). This is one source of a model we will discuss later (Model 3).

As was suggested at the outset of this section, the moral model is not dead: under its strong influence we find both Presidents and Marxists of our own time. This is hardly surprising, since, as Hobbes pointed out, underneath our social models we are talking about survival, whether it be personal survival, or the survival of our way of life - an inescapably moral question.

Model 2. THE FUNCTIONAL-ORGANIC MODEL

The first full articulation of a mechanical model of possible social collapse comes, like Marxism, out of the nineteenth century. It can be found, appropriately enough, in the works of the two founders of the modern study of society, August Comte and Herbert Spencer. Even more appropriately, they come out on opposite sides of the complexity question, Comte proposing an optimistic, somewhat Burkean model; Spencer proposing a more pessimistic, Rousseauist model.

Model 2a. OPTIMISM

In Volume 2 of his "Positive Philosophy", Comte concludes an evaluation of the growing complexity of modern society with the following observation:

> Although all the forces modifying society grow less and less intense, the reaction of the great being (Comte here refers to civilisation-ed.) over the fatality upon which it depends, grows ever more and more complete. We thus dispose of that serious difficulty which threatened us, when the conclusion of social

> statics seemed to point to a constantly increasing complication of society... Phenomena of all kinds, whilst they are growing more and more complex, at the same time are growing more and more capable of modification... and this (humanity) triumphs over the blind fatality encompassing its life... (Comte 1853).

This is the underpinning of the optimistic version of Model 2(2a). It is a progressive model, and it suggests that the human control of the earth, and the political and social systems which have evolved to accompany and direct that control, are capable of handling almost anything that "can be thrown at them". Not only is this because regularity necessitates modification of exceptional stress, but also because human institutions, ideas, manpower, technology, can all be harnessed to ensure adequate response to crises. Natural disasters call emergency response services into action; outside aid pours in; reconstruction begins. In their recent study of the drought in the Sahel, for instance, researchers at Clark University referred to a prevalent "lessening" hypothesis, which holds that the Sahelian peoples were able to enlist world support, call upon emergency advanced medical care, or depend upon extended families to cushion the shock of the 1972 drought to a greater extent than in the earlier droughts of 1910-1914.

In terms of more gradual social change, the model may be seen to work as a description of the ability of a society to alter its institutions (as, for instance, redistributing income) because there are enough reserves of material or enough cultural mobility to make such changes possible without causing major disruption.

A recent, and powerful, analogy to Model 2a, comes from ecology. Ramon Margalef, the Spanish ecologist, pointed out that:

> in a mature (complex) ecosystem the number of species is high, many species are physically and behaviourally specialized, food chains are long, population sizes are relatively stable ... A mature ecosystem confers environmental stability on its member species. (Ehrenfeld 1970).

The concept of ecological stability will be dealt with when we come to describe a later model. What is worth noting here, however, is the suggestion that the very complex richness of a society protects it. One natural example might be the power of genetic richness in bacteria or insects: though 99% of the populace may be destroyed, 1% will be immune; and, in the absence of competitors, that 1% will flourish, thus preventing the species in general from extinction. Richness is an inverse "firebreak" against extermination. Two social examples present themselves: in the case of stability of complexity, it has often been noted that it was the maturity of Byzantium which kept it alive for a thousand years; in the case of the resources of richness, a complex society can often substitute or rearrange itself in the face of threat, and, in the event of partial destruction, reconstruct at a lower level with existing resources.

One further advantage of a complex society is the spreading out of problems. One form of collapse can be pictured as a series of problems all suddenly coming into "phase", each reinforcing and accelerating the others. In line with Ashby's formulation that "only variety can destroy variety" (1960) - which crudely means that if you have an enemy with x tactics against you, x plus 1 independent countering tactics will give you control (Mackenzie 1978) - complexity may ensure that no set of problems strikes one system at one place in one time.

Model 2b. PESSIMISM

In his "Principles and Sociology", Hebert Spencer presents the first extended parallelism between a physical organism and a social organism, using many examples of the former to elucidate elements of the latter. He makes the following point a number of times:

> ...when (individual and social organisms) are little evolved, division or mutilation causes small inconvenience, but when they are much evolved it causes great perturbation or death, and that in low types of either kind the parts can assume one another's functions, but cannot in high types... as (society's) parts assume different functions they become dependent on one another, so that injury to one hurts another; until, in highly-evolved societies, general perturbation is caused by derangement of any portion... Middlesex separated from its surroundings would in a few days have all its social processes stopped by lack of supplies. Cut off the cotton district from Liverpool and other ports, and there would come arrest of its industry followed by mortality of its people. (Spencer 1897)

While this is an evolutionary model of sorts, it treats the hierarchical and specialized structure of a higher organism as a mixed blessing. Spencer would not have us return to the amoeba; but there is a cost involved to the evolved.

This model, Model 2b, invokes metaphors which compare society to a house of cards, a fabric susceptible of being rent asunder, and continually refers to "vital nerves" and "vital arteries". The New York Blackout of October 1965 is an often cited example of how society may be brought to a stop in the absence of a vital commodity; but paralyzing strikes, terrorist attacks on key industrial sectors, and, of course, most recently, the uncertain future of secure oil supplies, have all been put forward as appropriate evidence for Model 2b.

An example of its invocation is provided by Henry Kissinger, speaking before the United Nations in September 1974:

> (The) global economic system that we have come to take for granted is now under unprecedented attack. The world is poised on the brink of a return to unrestrained economic nationalism... (and) ... the collapse of economic order... The complex, fragile structure of global economic cooperation required to sustain national economic growth stands in danger of being shattered (cited in Rousseas 1979).

Or,

> For "interdependence" implies that even quite a small disturbance in some sensitive area of the world will be multiplied... In such a world of complex mechanisms and acute sensibilities any threat to the supply of oil (or any other vital raw material) must send thrills of pain to the most distant parts of the system (Hartley 1980).

And, once again, as with Model 2a, there is an ecological analogy to support the approach of Model 2b:

> All life on earth is linked together by an infinity of connections, and this vast structure is influenced by and influences inanimate properties of the planet... Small alterations in the environment, like the loss of a bolt from a machine or the addition of some grains of sand to a gear box, may have effects far out of proportion to their own physical significance (Ehrenfeld 1970).

MODIFIED MODEL 2

It is obvious that neither the totally optimistic nor the totally pessimistic model - true though one or the other may be - is of much use in assessing the full complex responses of real societies, since they represent extremes or grossly simplified world-views. It is the interaction and subsuming of one model by another that allows a strong assertion to be made that this is, indeed, the way complex societies handle crises. These modified functional-organic models are generated by different attempts to integrate aspects of 2a and 2b; and the result is a number of "modified optimistic" and "modified pessimistic" patterns.

Two of the most powerful (which I shall designate 2a→b and 2b→a) suggest - in varying ways - that one of the above models is "inside" the other. Both assume that there is some truth to Model 2a: that modern society has in fact ironed out many small-scale perturbations, but that, as two climatologists discussing climatic change put it:

> In essence, societal vulnerability to climatic variations has been transformed from the pre-technological condition of high-frequency low-amplitude risk to the present situation of low-frequency high-amplitude risk (Schneider and Temkin 1978).

Model 2a→b uses this phenomenon as the basis for arguing that a series of successes, or localized optimism, sets the stage for the one massive perturbation that may destroy society. Disease, natural hazards, etc., have been controlled or localized to the point where complacency or ultimate inadequacy promotes catastrophe. The classic example of this is the fighting of disease in the Third World, which results in vast population increase and vulnerability to starvation or devastating natural hazards. Smaller scale variations include building on flood plains protected by one large dam, or developing rust-resistant grains which eliminate the wild varieties that could provide new strains in the event of a universal blight on a monoculture.

To anticipate the discussion of resilience strategies, it has been suggested that Model 2a→b type collapses depend on using the resources of modern society to promote reliable standards of supply rather than qualities of resilience (Lovins 1977). A related aspect of this phenomenon is the curious result that the virtues of complexity and richness become a positive hindrance when Model 2a→b takes over from Model 2a. When Model 2a overloads, as it were, a great deal of damage can be caused by the inability of the remaining elements of the system to generate the basic requirements that a less complex system - one with fewer intermediate steps or fewer specific requirements - could handle with greater ease. A trucker's strike in a major city might be handled adequately for several days; but after that, it is impossible for urban dwellers to grow their own food fast enough or in adequate enough quantities for survival. An example of this was provided at the end of the Second World War, when the American embargo on Japan and the bombings of Tokyo forced most of the people of Tokyo to travel back and forth to the surrounding countryside bartering for food from farmers.

A more subtle version of the same model is the historical model of the superiority of barbarians over civilized nations, not only because the barbarians do not accept the basic values of the society they are trying to overthrow (not at the outset in any case), but because civilized nations are crippled by complexities of response, humanistic hesitation from the necessity of reciprocal barbarity. This gives the barbarian a freedom of manoeuverability denied to the defender (Hartley 1980).

The more optimistic Model 2b→a suggests that although Model 2b collapses may occur, they can be contained within a greater, more absorptive Model 2a. Herbert Spencer, again, provides a starting point:

> ...arrest of those commercial activities, governmental co-ordinations, etc., which constitute the corporate life of a nation, may be caused, say, by an inroad of barbarians, without immediately stopping the action of all units... Though when a civilized society is so divided that part of it is left without a central controlling authority, it may presently evolve one; yet there is meanwhile much risk of dissolution, and before re-organization is efficient, a long period of disorder and weakness must be passed through (Spencer 1897).

A recent evocation of this model has come from Torry (1979), in the analysis of the anthropological aspects of environmental hazard:

> Environmental hazards are typically regarded as constraining social organization only by limiting the ranges of feasible

> subsistence modes and by restricting the extent to which each is pursued. Individual cells, to be sure, may collapse, but the social system survives intact.

Both Model 2a→b and Model 2b→a are attempts to put some development in time or space into the basic conceptual framework. Together, they can be used to generate even more versions of each other, so that it is possible to see a whole mosaic of localized collapses and recoveries, of limits reached or cascades of crises at various points throughout the posited system. When these factors are brought into play, another level of complexity of response is added to the discussion. It is at this juncture that "limits to growth" and systems theory begin to present themselves as alternative modes of description.

Before moving to "limits to growth" and systems theory, however, it is worth describing a few of the aspects of social collapse that are perhaps more easily described - if not more correctly - in the terms we have been outlining.

While initial small-scale Model 2b collapses may well fit into the 2b→a optimistic conclusion model, the multiplication and intensity of these collapses may bring a society to the point where the critical question is not so much "How much can we handle?", but "How much can we let be destroyed without fatally wounding our society?" This is the *triage* model: some must sink, so others can swim. The converse of this is the concentration on the swimmers, rather than the sinkers. "What is essential to the maintenance of our system?" becomes the key question. This is the basis of the "theory of compressibility" as outlined by Morgenstern (1966). In essence, the theory is the study of the relations between key or kernel or core elements of society, and the more peripheral elements which sustain that core (or, again, *vice-versa*). Morgenstern draws on the experience of Nazi Germany's attempt to keep industries alive in spite of incessant Allied bombing.

Morgenstern's is a view of the maintenance of relative efficiency as being an essential quality of a resilient society; the opposite lesson can be drawn from the Russian experience:

> When the Russian State entered the war (WWI) it did so in a incomparably ramshackle, dilapidated, and inefficient condition. But this did not mean it was powerless. On the contrary, in one way the very fact that it was so inefficient, that power was so decentralized, that the bureaucracy was so incompetent, acted as a source of strength, for it gave to the State a quality of resilience that a more efficient and centralized régime might have lacked... The German invasion of 1941 is but another example of the amazing resilience of the Russian State. So long as the centre remained standing, almost any sacrifice could be endured, any loss undergone, any disaster overcome (Kochan 1963).

Whether centralized or decentralized, these are essentially models of preservation through time of a clearly recognizable entity. There is a range of alternative descriptions, which emphasizes the shifting increases and decreases in strategic positioning; in a sense, allowing for a form of adaptive response. Service (1975), in discussing the fall of civilizations, describes the perils of static success:

> It is also tempting to assume that there is in the nature of any specific form of government a critical population size, or scope of governance, beyond which its particular integrative institutions cannot cope... Similarly, it may well be that a successful policy, well adapted and "coherent" over a long period of time, becomes brittle or inflexible and thus cannot resist well, or easily adapt to, changing circumstances... But this factor, however likely, does not yet explain a society's fall, but only its failure to keep on rising. There is another aspect to successful adaptation that is now relevant: its radiating, expanding movement.

As well as indicating the continuing relevance of the suggestion made earlier that it is when a society goes on the defensive that its strengths may become weaknesses ("grow or die"), this description also introduces us to another kind of development in the face of stress: development at the expense of others. There is a number of examples of this type, but one deserves special attention, since it combines some of the themes we have already been discussing.

In the recent literature of natural hazards research, there has come into existence a school of researchers who assert that the Marxist model of imperialist underdevelopment of Third World countries can be applied to hazards research. They take their cue from the presumed interrelationship between disaster and development:

> Perhaps the most thought-provoking idea of all is that just as natural processes such as environment affect social structure, so social processes such as economic development can affect natural systems "causing" famine and soil erosion for example. This should make us think again about the term "natural" disaster (Richards 1975).

Torry has given a good brief description of this school, and its counterpart:

> ...the trend in (hazards) research has been either to ignore altogether developmental processes in social systems by focussing on roles, individual cognitive processes, or formal organizations, such as police and fire departments, operating within disaster contexts, or by lumping together different empirical instances of disaster together as special instances, or epiphenomena, of global development tendencies. Marxist attempts at explaining disaster vulnerability among Third World peasant communities as an inevitable product of the economic exploitation engendered in class-stratified capitalistic states exemplifies this approach (Torry 1979).

Buttressed by specialists in development problems (Biswas 1980; Harrison 1980), this description has been making headway. While by no means subscribing to the full Marxist model, one might however say that the developed countries have responses to stress that may be inappropriate for the lesser developed countries. It is generally agreed that it is the rapidly developing countries that are the most vulnerable to hazardous environments (Baird *et al.* 1975; Burton *et al.* 1978), since they combine the disadvantages of the loss of traditionally resilient social structures (Mair 1963), with the disadvantages of an as yet uncompleted and incompletely replacing social structure derived from technocratic models. The researchers on the drought in the Sahel, having referred to the "lessening" hypothesis (i.e. modern aid was speedily forthcoming), also put forward a "worsening" hypothesis:

> The Sahelian people were the victims of a colonial and neo-colonial international economic and technical order that had decreased their dependency and reduced their self-sufficiency by draining off the agriculturally important labour supply by migration, by creating technical conditions for a rapid increase in population and livestock numbers, and by adopting policies that favoured the small urban elites (Climate and Society Research Group 1979).

On the other hand, depending on the circumstances, this position between two worlds may be beneficial. Torry (1979) again:

> Where established procedures, policies, programs and bureaucratic structures fail under stress, novel approaches to problem solving which contribute to organizational modifications in state or local government may emerge, and these changes in turn stimulate economic development. The metamorphosis of colonial government in India attests to just this kind of relationship between disasters and development.

And, finally, it may have little impact at all. This is the experience of "broken-backed states", or countries with inappropriate or irrelevant governments. This term was borrowed by Tinker (1965) from post-nuclear-warfare theorizing to describe the persistence of semi-stability in countries such as the Union of Burma in the presence of a substantially ineffectual government:

> Where the web of governmental and economic life is so much more loose, and indeed more perfunctory than in our complex, highly integrated western systems, an almost complete breakdown of the national machinery does not entail a similar breakdown in local life. And so there is no dramatic national collapse. There is just broken-backed government (Tinker 1965).

We are reminded here of the case of the Russian State.

It is not too much to say that all these versions of coping with extra-ordinary stress on the part of societies owe what explanatory power they have to their intuitive illumination of a situation, modified through a generally functional-organic "common sense" model. But as the number of elements, their relative positions and relations, and possible transformations of elements, positions, and relations all begin to have to be taken into account, "common sense" begins to become counter-productive. One specialist in social systems theory notes:

> ... the human mind is not adapted to interpreting how social systems behave. Our social systems belong to the class called multiple-loop non-linear feedback systems. In the long history of human evolution it has not been necessary for man to understand these systems until very recent historical times (Forrester 1973).

In light of this, and in the light of developments in a number of fields, it has been suggested that more systematic models of the intuitive and counter-intuitive behaviour of societies can be developed through the use of models derived from ecological and systems theory.

Model 3. THE LIMIT MODEL

The full "limits to growth" model is, of course, dependent for much of its structure on systems theory; but the basic idea is simple and premonitory, since it forces society to look at the power of the exponential function and asserts that the isomorphism between that function and certain sectors of society will have the following conclusion:

> If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity (Club of Rome 1972).

As was mentioned earlier, the possibility that Western society would run up against a wall was discussed by Rosa Luxemburg early in this century, in deliberate contrast to the infinite world resource picture treated as an assumption by the Victorians (including Marx). The basic "limits to growth" model not only tries to map out what this run up to the wall looks like; but, more importantly for our purposes, tries to show what the wall will look like. The wall is an "overshoot and collapse":

> ...population and capital, driven by exponential growth, not only reach their limits, but temporarily shoot beyond them, before the rest of the system, with its inherent delays, reacts to stop growth (Club of Rome 1972).

As the modellers themselves point out, the second half of this sentence is the most important, since it is agreed that alterations of trends and the "human-value system" of growth is feasible. But:

> ...under contions of rapid growth, however, the system is forced into new policies and actions long before the results of old policies and actions can be properly assessed. The system is even worse when the growth is exponential and the system is changing ever more rapidly (Club of Rome 1972).

The stress is not on the system: the stress is on making sense of the rapid changes in the system. In other words, the resource which gives out first is time.

The earliest versions of the "overshoot and collapse" model are quite severe and universal:

> Population...peaks at the year 2030 (and) has fallen to one-sixth of the peak population within an interval of twenty years - a worldwide castastrophe of a magnitude never before experienced. Should it occur, one can speculate on which sectors of the world population will suffer most. It is quite possible that the more industrialized countries (which are the ones that have caused the disaster) would be the least able to survive such a disruption of the environment and food supply (Forrester 1973).

This is, of course, a restatement of our pessimistic Model 2b: it is the complex societies that may collapse, through disruption.

By the second report to the Club of Rome (Mesarovic and Pestel 1974), another view becomes more prominent, which is more like our modified optimistic Model 2b→a. An analogy is drawn between the exponential growth curves and the unbalanced and undifferentiated growth of, for example, cancer cells; so as to contrast that kind of growth with truly organic growth into organ-specific differentiation and equilibrium. One result of this analogy is to change the most prominent model from the general "overshoot and collapse" catastrophe to a compartmentalized model of pockets of horror, most often slowly increasing mass starvation in underdeveloped countries. The more industrialized countries are able to survive, since the rich can always command resources. There is thus no wall, no limit; rather the limit is like the farthest advance of a glacier: when it retreats, the parts at the edge melt away fastest and first.

There are technical objections to this model (both earlier and later versions) which can be briefly stated. First, as with Marx, the model keeps not happening. The two criticisms are: (1) that the interactions between the functions are just too complex to be put into a computer; and (2) the functions are inaccurate or already out of date. Second, exponential growth is not just the problem, it is also the solution (Kahn *et al.* 1976). Indeed, this second main objection incorporates the view that the whole "limits to growth" theory is itself counter-productive, since braking growth will kill more people than using growth. Third, and in the spirit of our optimistic model of social complexity,

> ...the cheerful sceptic...will say that we forget the time factor and what we shall have to face is not a simultaneous crisis on all fronts, but a succession of bottlenecks, of separate sources of stress, which can be tackled one by one; the defenders can concentrate forces, the attackers are dispersed (Mackenzie 1978).

While the modellers might not contend that one of the purposes of the modelling exercise was to locate these difficulties, it is nevertheless the case that:

> The result of a simulation experiment is essentially the answer to the question, "What would happen if the system under study had such and such structural and dynamic properties?" As has

> been repeatedly pointed out by serious practitioners or simulation, the greatest value of the method is heuristic (Rapoport 1966).

The learning process is two-pronged: (a) if the system has these properties, this is what happens with various inputs - this is the "limits to growth" process in this case; (b) if this is what is happening with various inputs, what then are the structural and dynamic properties of the system? - this raises the question of whether or not the systems model itself is appropriate. Systems theorists might argue that questions about what is in the "black box" are separate; but in dealing with political or social systems the conjunction is inevitable.

Model 4: THE SYSTEMS MODEL

What, then, can we learn from the systems model itself, of which the "limits to growth" model is an instance? The use of "social system" or "socioeconomic system" as a common synonym for "society" is widespread (the earlier sections of this paper exemplify the practice), which indicates a vague acceptance of the fact that society is a complex and interrelated whole, but little more. Definitions of "system" are notoriously available, but a few - in ascending order of relevance here - may be helpful:

> A system can be defined as a set of elements standing in interrelations (von Bertalanffy 1971).

> *A system* is a set of logical operations acting upon and acted upon by, one or more *inputs*. These inputs lead to the production of *outputs* from the system and this process of *throughput* is capable of either sustaining the operational structure of the system, or of transforming it, perhaps catastrophically (Bennett and Chorley 1978).

> Every *system* is a set of different elements or compartments or units, any one of which can exist in many different states, such that the selection of a state is influenced by the states of the other components of the system. Elements linked by reciprocal influences constitute a *feedback loop*. The loop may be *negative*, or *stabilizing*, like the one formed by a heating unit and a thermostat... or the loop may be *positive*, or *disruptive* like the spread of an annihilating epidemic (Margalef 1968).

> The sociocultural system is a unit system in which all the cultural information is a stabilized but constantly changing network of intercommunicating attributes forming a complex whole - a dynamic system (Clarke 1978).

Since a socioeconomic system is a relatively open type of system, it is exposed to influences or disturbances from outside - some benevolent, some not. We will forego discussion of the equilibrium-seeking aspects of the system for the moment, and concentrate on what these responses are trying to prevent:

> We can say that stress occurs when there is a danger that the essential variables [of a political system] will be pushed beyond what we may designate as their critical range. What this means is that something may be happening in the environment - the system suffers total defeat at the hands of the enemy, or a severe economic crisis arouses widespread disorganization in and disaffection from the system (Easton 1966).

A number of diagnoses of this type have been applied to the collapse of social systems. One of the best known is Eisenstadt's discussion of the failure of the empires. One of his main points is that the failure of empires can often be traced to the supersession of the orientations and goals of the system as a whole

by the always present - but harnessed or suppressed - orientations and goals of sub-systems within that system:

> In some of the historical bureaucratic empires, the contradictions in the respective orientations and activities of the rulers and the principal strata [bureaucrats, aristocracy, etc.] and their interrelations, became so strong that they undermined the basic conditions and premisses of the historical bureaucracies... The different specific political and administrative organs of these polities were not able to perform their functions of interrelating the political sphere with other social spheres and of insuring the mutual flow of resources among them (Eisenstadt 1963).

Eisenstadt provides a good example of the attempt to deal with the vexed question of how to cope with bringing human values and systems theory together in a usable "mix". In a sense, we are presented with the systems equivalent of the old mind-body question in philosophy: on the one hand we have organizations and economic interactions that appear to be amenable - or more amenable - to the more mechanical appraisal of some systems theories; on the other, these forms all are permeated with orientations,and goals, and values derived from - where?

Two major systems theories have attempted to deal with this issue. One, Talcott Parsons' theory, in the tradition of Max Weber, concentrates on action, "the structures and processes by which human beings form meaningful intentions and, more or less successfully, implement them in concrete situations" (Parsons 1966). Human action is, however, meaningful not in a vacuum, but in terms of the internalized cultural norms of the society to which individuals belong. Thus,

> The core of a society, as a system, is the patterned normative order through which the life of a population is collectively organized... To survive and develop, the social community must maintain the integrity of a common cultural orientation... (Parsons 1966).

So, for example:

> The Roman Empire did not develop a sufficiently integrated societal community, and failed to integrate all the major ethnic, territorial, and religious groups with reference to a single primary normative order standing for the whole society and above the authority of Roman government (Parsons 1966).

Parsons' explanation, as with Eisenstadt's, and as with the moral model tradition as a whole, essentially focusses on the binding "moral glue". Since Parsons does not belong to the "general systems theory" school, his systems are largely self-constructed explanations of varying empirical data; the same rich variety can be found in the patterns of normative order - it is, however, difficult to relate the systems and the patterns in a useful way.

The other major attempt has been to start from the systems and work to the patterns, through the "general systems theory" model:

> The Parsonian system claims to be empirical; general systems theory claims rather that it is axiomatic, in that the mathematics conceived first for the manipulation of electronic systems has been so far generalized that it is applicable to any system whatever, provided that the rules are followed: "systems are isomorphic" (Mackenzie 1969).

This is associated with the work of David Easton. Easton uses the notion that there must be a regulator, or control sub-system in the system; and that these "authorities" - which can be interactions of the political system - allocate the values for a society (Easton 1966). We cited earlier Easton's version of what happens when a stress pushes essential variables beyond their critical range. He goes on to say:

> Let us assume that, as a result [of disorganization or disaffection] either the authorities are consistently unable to make decisions, or the decisions they do make are no longer regularly accepted as binding. Under these conditions, authoritative allocations of values are no longer possible, and the society collapses for want of a system of behaviour to fulfill one of its vital functions (Easton 1966).

What Easton does is to abstract both value creation (let us call it politics) and administration (the implementation of values) from their multiplicity and social pervasiveness, and then asks us to look at them as if they were systems. In other words, if they can be seen when arranged systematically to behave like systems, treat them as such. This is a curiously circular procedure; but the main thrust of Easton's work is in the use of systems theory as the generator of questions about the possible relationship between the insights of systems theory (feedback loops, flow-models and the rest) and the elements of social systems, rather than in the assertion of a complete identity at every point.

Is there ultimately anything we can say about the use of this type of model - and its more mechanistic varieties - for the modelling of systems which are made up of human beings? There is a strong body of opinion that would reject the application of mechanically-derived analogies to human societies, simply because they do not belong in the same category (Winch 1958). This may be because humans are rule-guided beings; or it may be because humans are basically unpredictable. We rebel against the inevitability of disaster; just as we rebel against the imputation of determinism.

Two points may be made here, which will by no means even begin to deal with this vast and complex topic; but which may serve as a partial summary of what we have been looking at up to this point, and as an introduction to the next section.

The first concerns "inevitability". One of the things we saw when looking at the "limits to growth" model was that approaching the limits of various resources also implied approaching the limit of useable time. This is not just true of decision-making time. Wiener (1950) makes this observation:

> Thus in depending on the future of invention to extricate us from the situations into which the squandering of our natural resources has brought us we are manifesting our national love of gambling... If the food supply is falling short, or a new disease threatens us, inventions to relieve it must be made before famine and pestilence have done their work.

As decision-making time and invention-making time decrease, something else begins to happen:

> The dangers that perhaps impress us most are subtle ones. They revolve around the probability that, as human society makes greater and greater demands on available resources, margin for error decreases. As it decreases, a more and more interdependent, elaborate, and fail-safe organization is required simply to prevent the system from collapsing at the first perturbation (Ayres and Kneese 1971).

In other words, in some cases - perhaps our own - the system becomes more and more deterministic out of necessity. Simply put, one runs out of free space for free will to operate in.

This happens over and over again in history, and the phenomenon makes us assume certain events were "inevitable" in a similar fashion to the way social and economic conditions may make other kinds of events "inevitable". What actually happens is that opportunities for making choices and changes are continually missed

or ignored, and the focus grows narrower and narrower as more and more opportunities are missed, until, ultimately, the range of responses has been drastically cut down. In this unhappy way, the aspects of the system that were intractable before - the human values and choices - become more and more amenable to prediction, as if the approach to collapse was the basis for the derivation of a calculus of human behaviour.

The second point is that a key requirement for treating socioeconomic systems as systems is that the elements and relations obtaining among the elements be specifiable:

> As we move away from the systems considered in the physical sciences, the conceptualizations become progressively less rigorous... we have considerably greater confidence in the rigor, implied by the equations, to chemical than to ecological systems... As we move to social systems, even the elements and the relations are ambiguously defined (Rapoport 1966).

In general:

> ...the system approach to political theory amounts to an attempt to theorize about political bodies and political events in terms of precisely specifiable structural and dynamic characteristics (Rapoport 1966).

This kind of consideration leads Easton to conclude:

> ...theory needs to find out how any kind of system manages to persist long enough to continue to make such decisions [on political allocations] and how it deals with the stress to which it may be subjected at any time (Easton 1966).

This suggests that one way forward is the examination of "resilience" and "vulnerability" - how a system persists, and how it deals with stress. Not only that, but the examination can be usefully carried on in terms of the conceptualisation of these terms. Furthermore, as we shall see, both these terms derive support from certain aspects of systems models, both "general" and ecological. We shall turn to "vulnerability" first.

"VULNERABILITY"

The models we have been examining emphasize different aspects of socio-economic systems in the face of stress, even though they are not sealed off from one another. One model emphasizes the moral "glue" binding the elements together. Another model emphasizes the localized elements in the system; one draws boundaries to the system; and one treats the complex interrelations of the maintenance of all these characteristics as a whole. Now it can be said that each of these features separately and together are "vulnerable". Is this of any use as a description or a concept?

It is certainly the case that "vulnerability" is useful rhetorically: the introduction to this paper charted the rise in concern which has forced us to consider the idea, if not the term. And yet, "vulnerability" is a term of such broad use as to be almost useless for careful description at present, except as a rhetorical indicator of areas of greatest concern. For a start, vulnerability has only one true opposite - invulnerability - which probably does not obtain in the real world.

This - like the unbalanced relationship between "safe" and "hazardous" - has been part of the heritage of the word since it made its first appearance in the English language:

> Let fall thy blade on vulnerable crests, I bear a charmed life.
> (Shakespeare's *Macbeth* v.viii. 11)

Macbeth imputes invulnerability to himself - vulnerable meaning "woundable" (from the Latin *vulnerare,* to wound) is defined in opposition to the supernatural and for our purposes, the impossible.

It is in consequence hard to prepare a scale of degrees of vulnerability to replace this curious lack of graded opposition, since the slightest vulnerability, unaccounted for, may precipitate collapse (the "Achilles heel" effect). For example, during World War II, the British had a vast, impenetrable fortress guarding Singapore. The only vulnerability was that the expectation and defences were all geared for seaward attack. When the Japanese came down the peninsula instead, Singapore fell. Not only does the "Achilles heel" effect function in that way, it also happens that the more (presumed) invulnerable you are, the greater your fall when that massive shielding fails: this is another version of our Model 2a→b.

What we are left with is a simple comparative (this is more vulnerable than that) or a warning (we are increasing our vulnerability to this or that danger) or the use of the word in conjunction with another, the other word by contrast indicating the supposed character of the vulnerability - this is the basis for the "vulnerability" and "resilience" contrast, as will be described below. In recent research, all of these usages have become intermingled.

For example, within the general framework of risk assessment, there has been an exploration of the relationship between a potentially hazardous event and the potential vulnerabilities of the recipient of that hazardous event, so as to provide something akin to a "risk context":

> Vulnerability, therefore, will refer to the threat to which a community is exposed, taking into account not only the properties of the chemical agents involved [Sc. hazardous materials] but, also, the ecological situation of the community and the general state of emergency preparedness, at any given point in time (Gabor 1979).

In this quotation, the hazardousness of a product is being matched against the susceptibility of a community; both characteristics having presumably been separately determined in previous matchings (at the very least, in the testing of the toxic properties of the product). In Zajic and Himmelman (1978), for instance, the vulnerability of a community to hazardous materials spills is calculated by taking into account frequency of transportation, population densities, levels of hazardousness of particular chemicals, and the results of a questionnaire into emergency plans for the area. This is then transformed into a vulnerability index for each community.

This model has been critisized for utilizing both highly aggregated data, and only partial data to make up the index (Gabor 1979). More pertinent criticism might be that the matching method is either a glaring example of a circular argument; or it is at one more level of generality away from the already controversial overlay of the general determination of hazardousness itself.

Another example of the use of the term "vulnerability" comes in the description of stressed ecosystems. Cairns and Dickson (1977) have borrowed the term:

> *Vulnerability* is defined as the ability to resist irreversible damage (which is defined as damage which requires a recovery time greater than a human life span). Presumably it is measured by the size of disturbance necessary to cause irreversible damage. (cited from Kay, unpublished)

This definition begins by focussing on the system's characteristics, but is then drawn almost inevitably into dealing with the characteristics of "out there", i.e. "the size of the disturbance". This once again illustrates the two-faced

nature of the concept of "vulnerability": one is vulnerable to attack *from*, thereby exposing one's vulnerabilities *to* - the hazards out there are somehow part of one's internal weaknesses. Any useful employment of the concepts has to keep this systematic ambiguity firmly in mind.

As it stands, the ecological definition is unsatisfactory, since "size of disturbance" is a particularly unwieldy way of determining "ability to resist". The definition is much too narrow (why should vulnerability be irreversible?), without thereby resolving the ambiguities. Of course, in Cairns and Dickson's work, vulnerability is only one of four descriptors of stress recovery characteristics. The others include elasticity (ability to recover after displacement), inertia (resistance to displacement), and resilience (the number of times a system can undergo a disturbance and still snap back). In a more systematic exposition of their approach, it might be that this "mix" adequately fills out the meaning of "vulnerability" through comparison and contrast.

Indeed, this method of filling out the meaning is, as mentioned above, one good reason why "vulnerability" and "resilience" have become linked recently; as if "resilience" were somehow the inverse or opposite of "vulnerability". This paper argues instead that "resilience" is, if anything, a much more restricted concept than its companion. This, perhaps, makes it also much more useful.

Having briefly explored the aspects of "vulnerability", let us then turn to "resilience".

"RESILIENCE"

"Resilience" has a tradition of exact definition behind it which is not matched by "vulnerability". In general, it is almost synonomous with elasticity, and is defined in the OED as "the art of rebounding, or springing back" from the Latin *resilio*, jump back. It is a useful technical term in mechanical engineering:

> The quality of being able to store strain energy and deflect elastically under a load without breaking is called "resilience", and it is a very valuable characteristic in a structure. Resilience may be defined as "the amount of strain energy which can be stored in a structure without causing permanent damage to it" (Gordon 1978).

This latter definition is remarkably similar to Cairns and Dickson's definition of "vulnerability" - indicating one of the ways in which the terms can come to be interrelated.

The use of "resilience" as a term describing the ability of a society to bounce back from severe stress is increasing (e.g. Burton *et al.* 1978; Climate and Society Research Group 1979). An almost direct line can be traced from its use in ecological systems theory to its use in the derivation of possible management concepts (Holling 1973; 1978). In much of the systems work, the concept of "resilience" is used to describe the response of certain systems to perturbations.

We saw earlier that if a socioeconomic system is seen as a relatively open system, it is (according to theory) necessarily exposed to influences from outside; and, since some of these systems (at least) have survived, they have clearly been able to respond or adapt to these influences. Of the strategies of response, homeostasis - the self-regulating, self-stabilizing action - or the subtler variation of homeorhesis - the stabilizing of a progressive system which acts to ensure that the system goes on altering in the same sort of way that it has been altering in the past - are the best known (Waddington 1977). As Easton notes:

> It is then customary to analyse the system, if only implicity, in terms of a tendency to return to a presumed pre-existing point of stability. If the system should fail to do so, it would be interpreted as moving on to a new state of equilibrium (Easton 1966).

It should be pointed out that there is a variety of equilibria:

i) stable equilibrium - a small displacement from the equilibrium point is cumulatively diminished.

ii) unstable equilibrium - a small displacement from the equilibrium point is cumulatively increased (often to a new equilibrium point).

iii) "domain of attraction" equilibrium - combination of i) and ii) where small enough displacement is diminished and large enough displacement is increased, thus mapping out a local area of stability.

iv) metastable equilibrium - a system which is only stable in the absence of a suitable catalyst, the introduction of which usually results in a transition over some "threshold".

v) steady-state equilibrium - state only stable in the presence of certain constantly maintained variables.

vi) dynamic equilibrium - state stable in spite of constantly changing values of components, which successively approximate to a stable state.

vii) statistical equilibrium - components of the system are maintained according to certain probabilities of the frequency of their occurrence.

(adapted from Clarke 1978; Holling 1973; 1978)

Ecological systems modelling contends that some of the more complex variations outlined above in the drive towards equilibrium are better able to describe events in the ecosystem than the simple return of a mechanical system to a pre-existing stability. One such variation, for instance, would allow for small-scale fluctuations about a "domain of stability" (or of "attraction"), massive displacement from which results in divergence, either to a new domain of stability or to extinction.

An example of the complex events these models are trying to map out is provided by the spruce budworm. The interactions between the spruce budworm and the spruce-fir forests of Eastern Canada show (very roughly) that major outbreaks of budworm are very rare, and that they only occur after

(a) a series of unusually dry years, and,

(b) overcrowded stands of spruce and Balsam Fir.

The destruction of the Balsam by the budworm aids the spruce population, which also thereby helps to eliminate the diet of the budworm, thus returning the budworm to a lower and equilibrium state - not so many budworms as to destroy the forest, not so few as to be eliminated permanently. This interaction is best represented as creating a domain of stability which is occasionally exceeded by variations of climatic output (the dry years). While, as a whole, the system seems erratic and unstable, it has a resilience which depends on occasional fluctuations to ensure the budworm's food supply and the system's continuance. Resilience thus becomes a key characteristic in the description of the persistence of such systems.

We are now in a position to cite Holling's definition of "resilience" in a ecosystem context:

> Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters,

> and still persist. In this definition resilience is the property of the system and persistence or probability of extinction is the result. Stability, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it returns, and with the least fluctuation, the more stable it is. In this definition stability is the property of the system and the degree of fluctuation around specific states the result (Holling 1973).

The value of Holling's definition is that it separates "resilience" from equilibrium or stability *per se*, and focusses on "resilience" as a function of "probability of extinction". If we now recall some of the aspects of the other definitions we have been exploring in relation to "vulnerability" and "resilience", we can use this new formulation as a starting point for an elaboration of our own.

For a start, if we accept for the moment that resilience has to do with the persistence of a system, it is at once obvious that "vulnerability" and "resilience" are by no means simple reciprocals. There are many "woundings" that do not affect the persistence of a system at all, but merely require either extra effort on the part of the system, or the elimination of freely expendable units. Resilience is just one of the possible vulnerable characteristics of a system. But - and this is critical - resilience is the one characteristic of a system which, when it is impaired, also impairs the persistence of the system. We can now begin to re-introduce those parts of previous definitions that refer to crippling or irreversible damage.

What we find ourselves moving towards is a variation of Morgenstern's theory of compressibility (see above, page 10) which would not be simply periphery *versus* centre; and which would focus attention on resilience instead of on vulnerability. This could be expressed as follows: in any socioeconomic system, there are numerous possible threats (internal and external) and numerous vulnerabilities. Of these vulnerabilities, it is those that, if impaired, would threaten the continued persistence of the society that are the most important. These qualities or elements of the society are ultimately qualities or elements of resilience, since their impairment puts in jeopardy the regeneration of crippled parts, the recreation of social cohesion, and the restoration of equilibrium at any point above catastrophe. This degeneration can be both physical and moral; and, indeed, if moral and political factors are at the heart of the control of the system, then destruction of resilience there is even more catastrophic than destruction at the physical level. A strategy promoting resilience would therefore seek to protect and strengthen the qualities or elements of resilience. One way would be to assess various vulnerabilities to see if, in fact, they were among these key resilience factors. Another would be to measure the amount of stress a sector could withstand before it became crippled, i.e. lost resilience.

We can sum up this part of the discussion, perhaps, by presenting two definitions of our own, incorporating some of these ideas:

> *Vulnerability* is the degree to which a system, or part of a system may react adversely to the occurrence of a hazardous event. The degree and quality of that adverse reaction are partly conditioned by the system's
>
> *Resilience*, the measure of a system's, or part of a system's capacity to absorb and recover from the occurrence of a hazardous event.

DEALING WITH UNCERTAINTY

The discussions and the definitions outlined above present a case for a strategy of resilience as part of an overall strategy to reduce vulnerabilities. This brings up once again the much-vexed question of the appropriateness of models - in this case, ecological models. Although this paper does not provide scope enough for a discussion of this point (for which see Rappaport 1977; and others), Holling provides us with a way of talking about the relations between resilience and social strategies, when he remarks:

> In order to determine the resilience and robustness of policies, it is necessary to assess their sensitivity to the unknown as well. One predominant type of unknown concerns uncertain objectives... (Holling 1978).

This suggests that another fruitful avenue of exploration is provided by the risk assessment literature, concerned as it is with dealing with the management of hazards under the condition of uncertainty; since what we are ultimately looking for is the incorporation of "vulnerability" and "resilience" into a reasonably explanatory model of a society's reaction to the possible impact of a possible event.

As was hinted at in the section on "vulnerability", "hazardous" as a concept has a parallel ambiguity: hazards are "out there"; but they are intertwined with what they threaten. This has been recognized in, for example, the natural hazards literature:

> *Natural hazard* was defined as an interaction of people and nature governed by the co-existent use of adjustment in the human use system and the state of nature in the natural events system (White 1974).

This is also true for the related concept of "risk". While one school sees "risk" as synonomous with "hazard", and another with probabilistic statements about events and their consequences; a third sees "risk" as "the probability times the consequence of an adverse or hazardous event" (Whyte and Burton 1980) - this third group emphasizing the interactions of "the human use system" and "the natural events system".

In fact, there is a clear relationship between risk assessment and assessment of "vulnerability" or "resilience". Here, for example, is a rubric for assessing risk assessment methods:

> Some of the initial questions that should be asked before any assessment methods are selected are:
>
> 1. Is the problem an analysis starting from a suspected (or known) *cause* or *effect*?
> 2. How is the problem distributed geographically? (highly localized, regional, national, associated with urban areas, in lowlands, etc.?)
> 3. How much time available is there to assess the risk? (fast or slow causes, acute or chronic effects?)
> 4. Where do the effects lie (within which demographic populations or which parts of the environment?)
> 5. Is the target (receptor) normal or particularly susceptible? (healthy adults or sensitive groups; unstressed ecosystem or already highly polluted?)
> 6. Are the effects reversible or irreversible? (Whyte and Burton 1980)

Three of these - 4, 5, 6 - are "resilience" questions.

The relationship may be more fruitfully explored if we borrow a definition of "hazard" from Clark (1977), who has suggested that a definition of a "hazard" as "the inability to cope" replaces simple minimization of risk with a range of coping strategies. The definition is inadequate - many hazards are easily coped with - but it does strongly emphasize the role of individual and social response; and, in the long run, suggests a strategic framework within which the concepts of vulnerability and resilience may play their parts.

If we redefine a "hazard" as an event, or an object, or a pattern of events and objects that potentially requires a coping strategy, we are then presented with a universe of possible events (or objects, or pattern of events) only some of which may require a coping strategy (see Fig. 1). The location of these possible events may be referred to as *hazard mapping*. The existence of a requirement for some form of coping strategy binds the hazard event to the possibly impacted system.

The probability that the particular hazardous events will be realized (instantiated) anywhere in the relevant universe is the assessment of the *risk*; and the mapping of *those* probabilities is *risk assessment*. Social evaluation (Kates 1978) or *impact assessment* provides the general heading under which may then be subdivided two descriptions of: first, the probable adverse relation between the instantiated events and the elements of the social system, which is *vulnerability analysis*; and, second, the probable outcome of this relation, which is *resilience analysis*. *Vulnerability analysis* and *resilience analysis* would not, therefore, be mutually exclusive: the first primarily addresses possible losses; the second primarily compensatory strategies - but neither of them mean anything unless there is a range of hazards requiring coping strategies. More to the point, then, a *vulnerability* could be considered as a passive form of hazard, i.e. a vulnerable area is the place where a hazard may become realized.

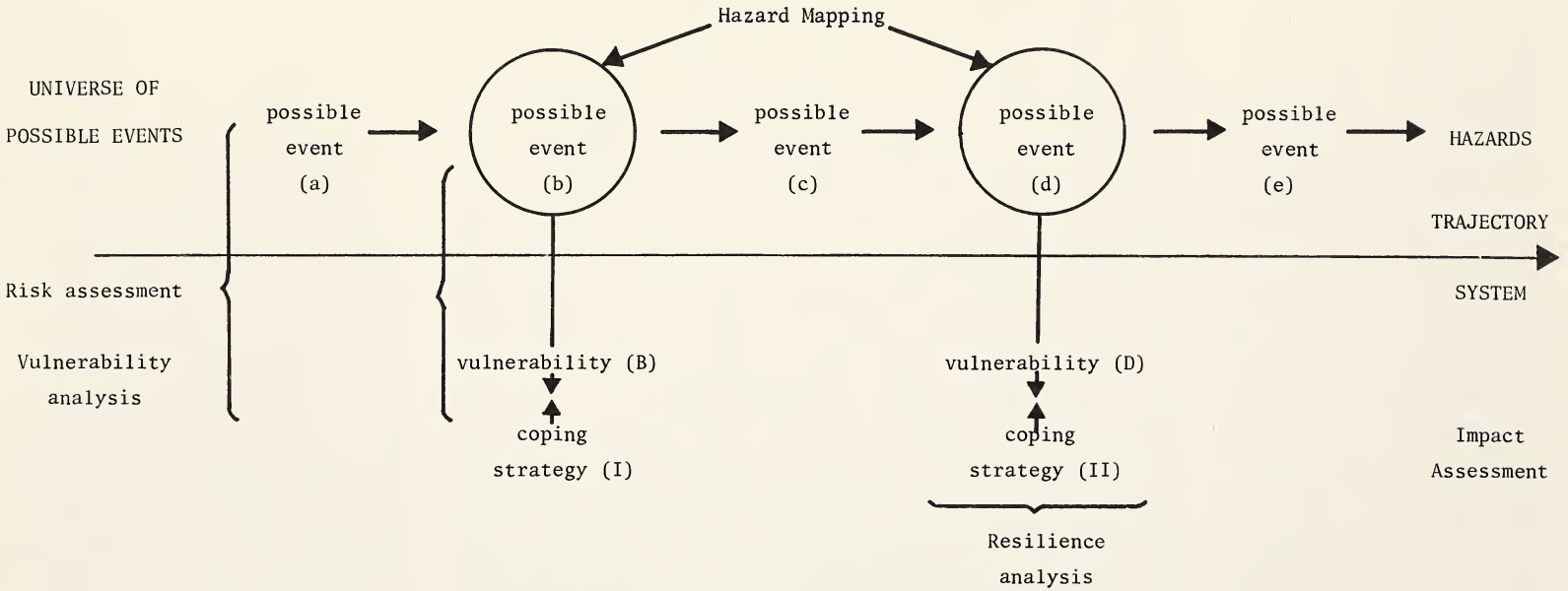
Resilience analysis is, of course, not just concerned with the way a society copes or would cope with the probable adverse consequences of a hazardous event; it is also concerned with the continuation of the possibility of coping, and, as described earlier, this must be the key concern of this kind of analysis.

What kinds of things would a resilience analysis seek to describe? One example is provided in a systematic model of socio-cultural and environmental interaction proposed by Clarke (1978), which fits rather well into the hazard mapping program sketched out above. In this model (see Fig. 2) of homeorhesis by self-regulation, a system reacts by controlling its own responses to various stimuli. A particular environmental disturbance, coupled necessarily to a system (this matches the hazard coupling above), calls forth a response from a regulator ("R") which bases its response on the experience of past events and past responses (and to which we could add the assessment of the present capacities of the system). The resulting outcome is drawn from the thus constrained table of possible responses "T". A new state is created out of the perturbations affecting the old, and the next state of the system will be created out of the perturbations affecting the new, and so on.

Clarke describes the regulator as follows:

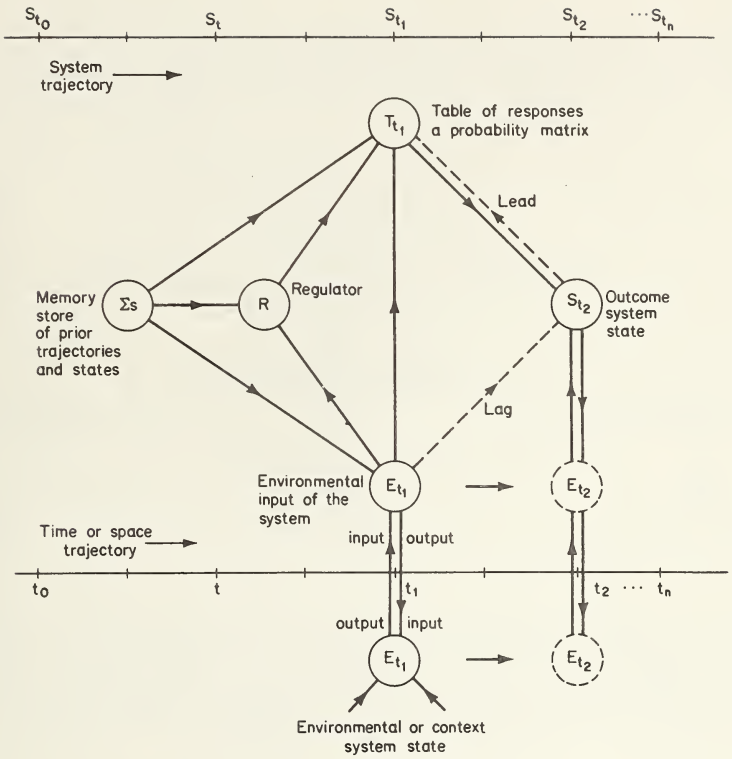
> The importance of regulating and controlling subsystems of this kind is their capacity for acting as an "insulating" medium between the system and its environment or context. The regulator blocks and filters the extreme range of external fluctuations by constraining their variety and maintaining the essential system parameters within certain limits. From the point of view of survival, systems integrating good regulating subsystems are better able to survive unchanged than similar systems with less efficient "insulation" (Clarke 1978).

Resilience analysis then, could address questions of the quality of the integration of these systems under stress, their "insulating" or buffering capacity, the successful transmission of their information and the ability to transform themselves under fire.



1. Events b and d represent possible *hazards*.
2. The location of events b and d of the universe of possible events a, b, c, d, e, is *hazard mapping*.
3. The probability of the instantiation of events b and d is the *risk* of occurrence.
4. The mapping of these probabilities is *risk assessment*.
5. The characteristics of the affected social system are described by *impact assessment*.
6. The probable adverse relation between events b and d and elements of the social system is described by *vulnerability analysis*.
7. The probable outcome of this relation as defined by the quality of the coping strategies B and D and the vulnerability of the system is described by *resilience analysis*.

Fig. 1.



The elements in the model are:

- S a continuous system, with a trajectory whose successive overall states are $S_{t_0} \ldots S_t$, S_{t_1}, $S_{t_2} \ldots S_{t_n}$, where $t_0 \ldots t$, t_1, $t_2 \ldots t_n$ are successive and infinitesimally small intervals along a time-trajectory (which can alternatively be considered as a geographical space territory at one given time – with the system varying contemporaneously over an area).
- S_{t_1} then represents the state of system S at point t_1; S_{t_2} at t_2, etc.
- E is the environmental system or external context coupled to and containing system S.
- E_{t_1} is then the state of the environmental or context system at point t_1; E_{t_2} at t_2, etc.
- T is a matrix or table summarizing the observed frequencies or probabilities of the possible set of outcomes or responses by S, under given conditions.
- T_{t_1} is then the state of the table T at point t_1, giving the probabilities of certain states of S occurring.
- R is the regulating subsystem which blocks and filters the extreme range of external fluctuations by constraining their variety and keeping the outcomes in table T within certain limits.
- Σs expresses the set of past conditions or prior states of the essential variables, through which the trajectory of the system has passed, up to the point in question – the 'memory' store.

Fig. 2. General model (c) - A model for archaeological processes. A model suggesting that archaeological entities, at several levels, change as special kinds of dynamic systems coupled with environing or contextual systems. (from Clarke 1978)

But what of the more general nature of the systemic response? What of its relationship to "out there"? If this is to be analysed, both the stimulus from the environment and the range and pattern of responses should be addressed. A useful interaction model (adapted from Feibleman and Friend 1945) sets this out:

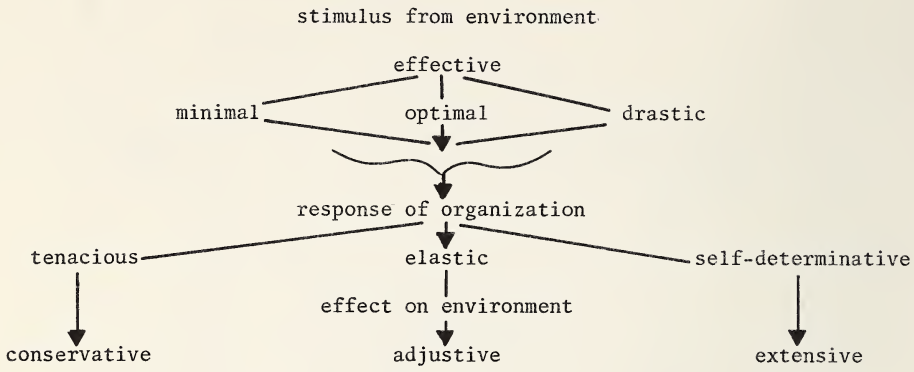


Fig. 3.

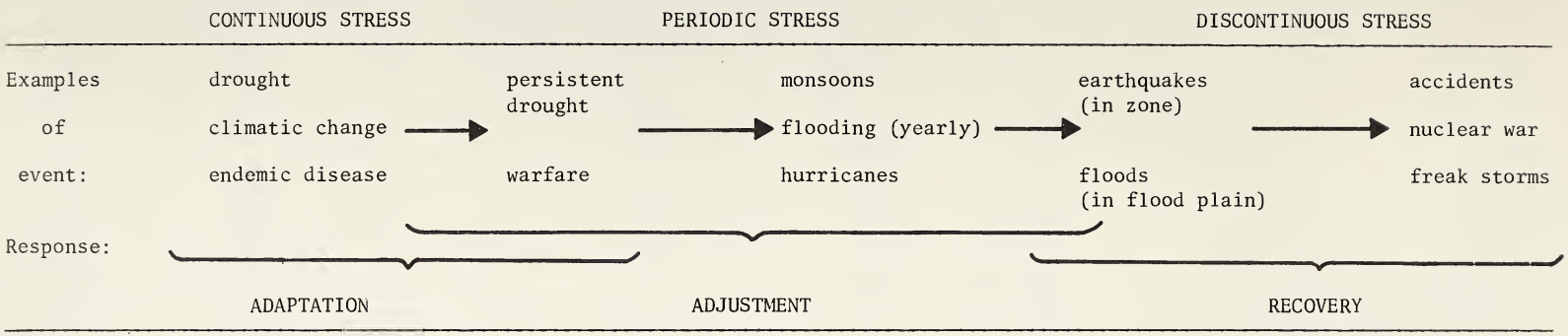
Working from the top down, we must be able to integrate the type of stimulus (or stress or perturbation), the adjustments or adaptations of the system under stress, the impacts which provoke the adjustments or adaptations, and the overall character of the interactive model. Briefly, then, we need finally to sketch out where materials for this integration are to be found:

I. STRESS

The type of stresses a society must deal with dictate to a large extent what priorities are given to what coping strategies. These stresses fall into three categories: continuous, periodic, and discontinuous stress (see Fig. 4). Recalling the first hazard mapping outline presented earlier, it should be clear that the three categories represent characterizations of configurations of events on the "event horizon". In the accompanying figure, the events should be seen as a spectrum from continuous (or long-term) stresses such as permanent climatic changes to extreme single events. Response to continuous stress may, over a short period of time be a simple adjustment, but over the longer term leads to permanent adaptations. Discontinuous events depend a great deal on their magnitude if they are to provoke adjustments beyond recovery, i.e. a disaster which occurs only once, but need only occur once to destroy society may have a higher priority than lesser disasters which occur with greater frequency - compare the fears over nuclear meltdowns with the fears over mining disasters. Discontinuous events that show some periodicity (and thereby predictability of a sort) such as hurricanes straddle uneasily the responses of recovery and adjustment. Periodic events that occur regularly, and are therefore virtually continuous, may well cause adaptations as well as adjustments.

II. ADJUSTMENTS AND ADAPTATIONS

The natural hazards literature has distinguished between these two strategies, mostly on the grounds of extent of the stress responded to over time (see Fig. 5). Anthropologists, working on the evolution of social systems, seem to concern themselves more with hierarchies; that is, "lower-order" regulators are continually dealing with perturbations which call forth reversible, high-energy, fast responses - thus ensuring behavioural flexibility. This is part of a larger and longer-lasting trade-off between adaptive flexibility and adaptive efficiency, since higher-order efficiency requires permanent alterations reducing flexibility (Rappaport 1977). This may be more generally applied to such social planning activities as the



Overlapping indicates that, for example, recovery from a discontinuous stress may not involve any adjustment for future re-occurrence of the event, if there is little expectation that the event may recur. If there is some probability that the event may recur, adjustment may be made. Adjustment may then be made on the basis of periodicity or non-periodicity. If the event has a large enough impact, even a discontinuous stress may result in permanent adjustment or adaptation (recurrence of any kind would be fatal); lesser impacts with more periodicity may also result in permanent adjustment or adaptation. Long-term, continuous stress likely requires adaptation.

Fig. 4. Social systems under stress

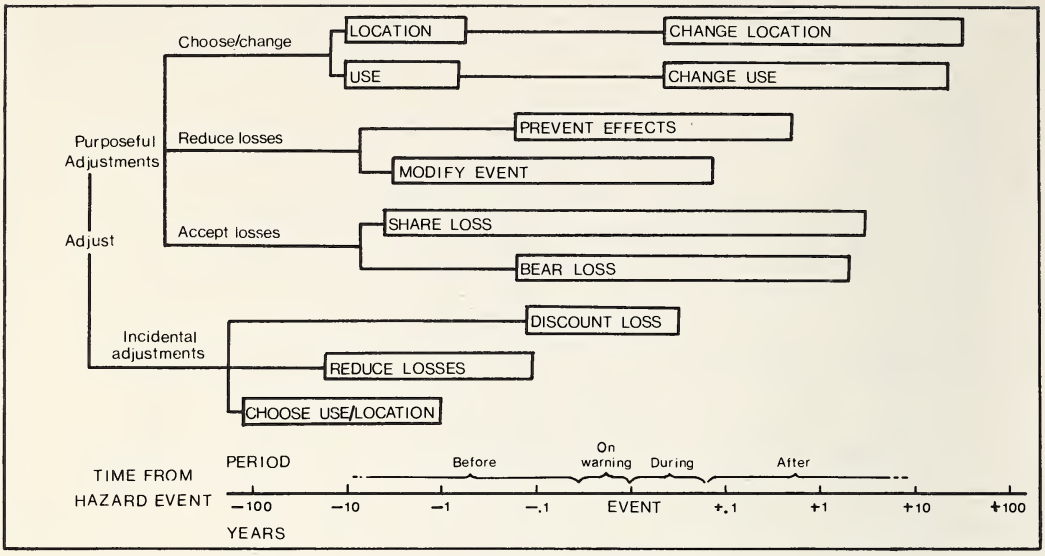


Fig. 5a. A choice tree of adjustment (from Burton *et al.* 1978)

Adjustment begins with an initial choice of a resource use, livelihood system, and location. For that choice various incidental and purposeful adjustments are available, at somewhat different time scales for initiation. The most radical choice is to change the original use or location.

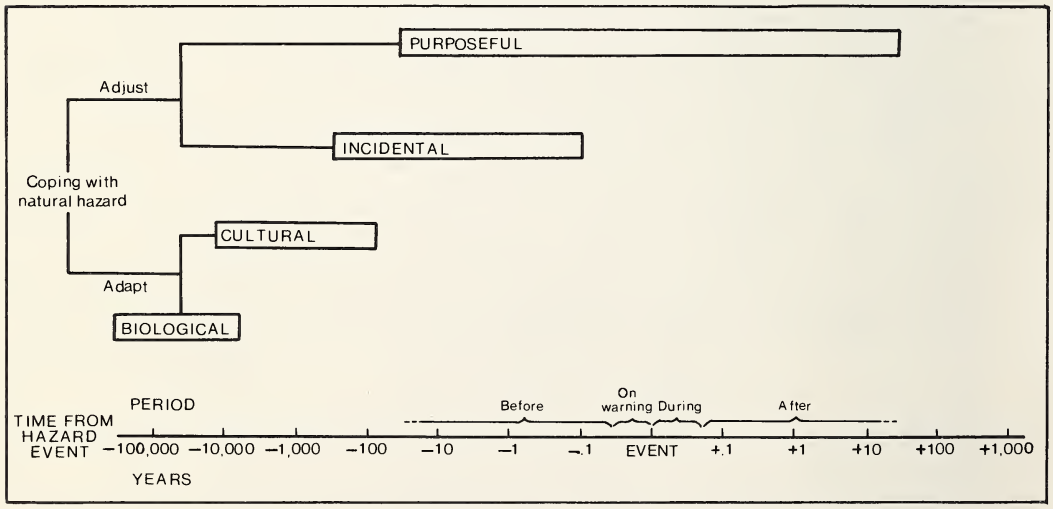


Fig. 5b. Time scale for coping with natural hazards (from Burton *et al.* 1978)

The four major types of response or ways of coping with hazard involve very different time scales in order to affect a hypothetical event.

installation and maintenance of warning systems, where preparedness for fast response has priority over planning for the reduction of intrinsic vulnerabilities:

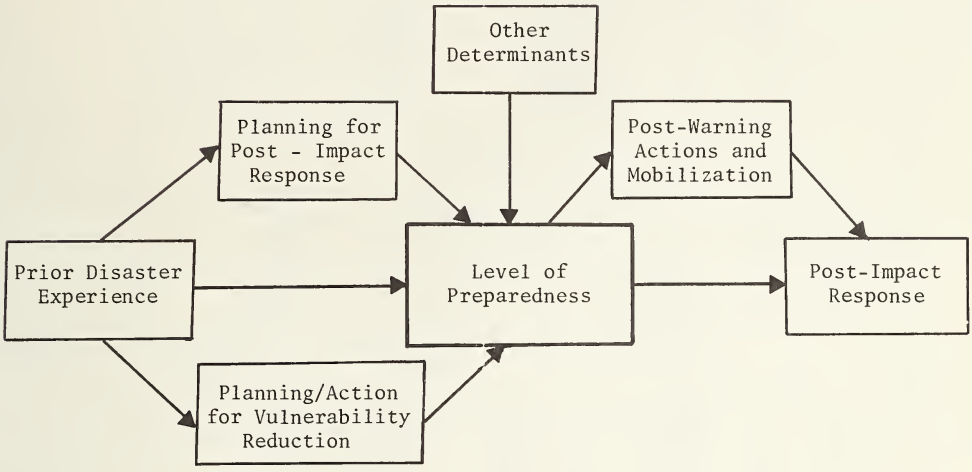


Fig. 6. (from Mileti, Drabek and Haas 1975).

III. IMPACTS

Prior adjustments and adaptations, an intrinsic part of any modern society's range of options, depend both on the perceptions of where possible dangers may arise, and on the assessment of what sectors are most likely to be endangered. The assessment of the impacts (taking the climatic sector again) is - as has been noted earlier - at the most rudimentary level, because tools for analysis are not yet available for talking about the ranges of response and the intricate social mechanisms which modify response. The Meyer-Abich model (see Fig. 7) from the ICSU/SCOPE Workshop on the Climate/Society Interface, is most notable for the way that the procession from level to level, from climatic parameters to political processes, is accompanied by step-by-step increases in the vagueness of what can be modelled or measured. More to the point, each level becomes more and more inseparable from the next level - to the point where economic indicators are as much a function of socio-political concerns as they are of climatic parameters or the equivalent, and just as immeasurable for predictive purposes.

A drought impact framework proposed by Warrick and Bowden (1980) displays a whole hypothetical set of pathways and linkages of impacts, but also allows for the articulation of the shift over time from horizontal level stresses to vertical stresses (see Fig. 8). In the drought framework, drought impacts prior to the 1930's followed horizontal or local paths; while today there is concern that a more vertical - national or global - impact pathway could result from a major drought. It is hardly co-incidental that we are once again brought up against the "vulnerability" ambiguity, for although the framework suggests the pathways and linkages of stress, it also suggests that the more vertical the pathway the more expansive is the possible management response.

This brings us back, in a broad circle, to some of the concerns with which we began. The national or global concern with developing managerial strategies arises on the one hand from the disconcerting lack of higher level data with which to gauge the "further order" impacts of events; and, on the other hand, from the lack of models to match the possibilities of social change.

Fig. 7. Stratification of climatic impact

No.	Level of impact	Disciplines relevant to analysis	Change occurring in	Examples of specific impacts		
				1 (natural fluctuation)	2 (natural fluctuation)	3 (man-induced change)
1	Climatic parameters	Climatology, oceanography	Temperature, rainfall, radiation, etc.	Change of temperature	Reduced cloudiness	Increased CO_2 content and rising temperatures
2	Potential related environmental change	Ecology, physical geography	Ecosystem and habitat changes etc.	Change in length of growing season	Better recreational climate	Altered energy and water balances
3	Human activity	Economics, sociology, psychology, geography, anthropology	Agriculture, energy use, tourism, transport, construction, manufacturing, etc.	Altered agricultural production: redistribution of such production	Tourism gains	Altered agricultural production, redistribution on such production
		PERCEPTION				
4	Social response and interaction	Sociology, psychology, geography, anthropology	Employment level, migration, culture, social conflict, etc.	Human migration, social conflict, employment changes	Employment gain	Human migration, social conflict; employment changes
5	Political processes and responses	Economics, political science, law	Legislation and regulation, legal action, research and development programs, international action and policies	Incentive programs for industry, agriculture, forestry	Expanded infrastructure, etc.	Energy conservation, change of power sources, precipitation enhancement, genetic research, etc.

(ICSU/SCOPE 1978)

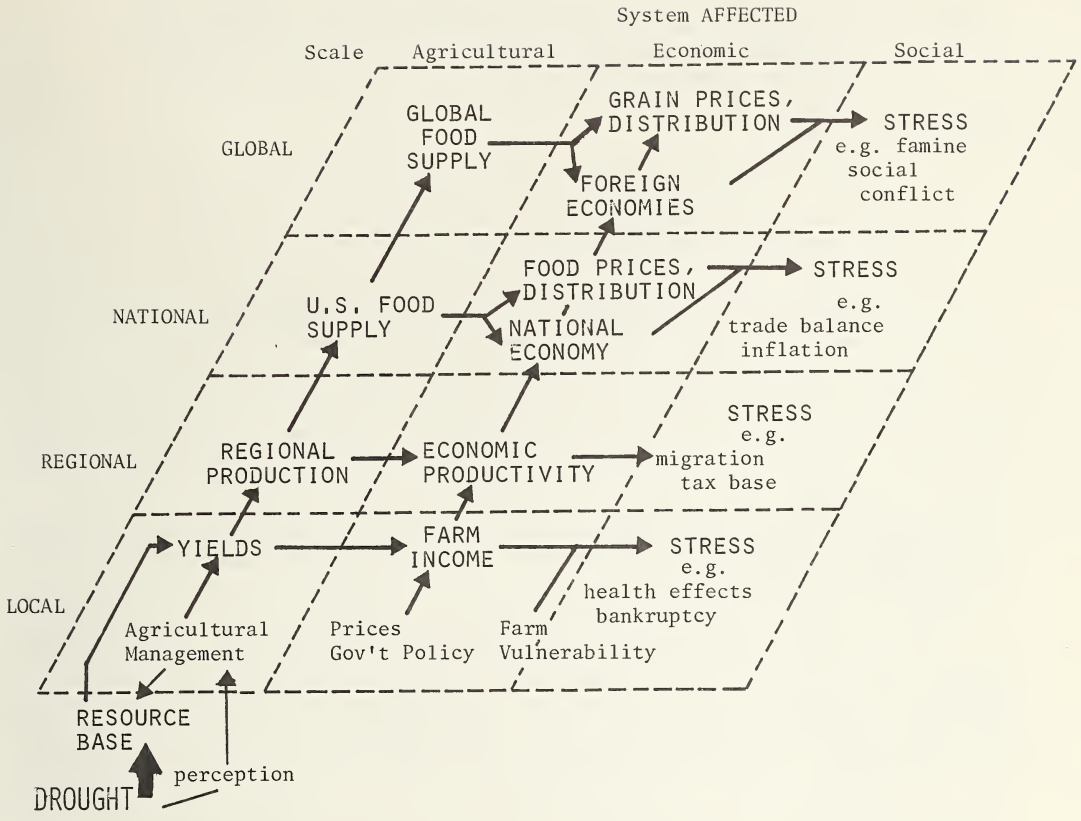


Fig. 8. Pathways of drought impact (from Warrick and Bowden 1980).

"RESILIENCE" *versus* "RELIABILITY"

What the last section implies is that there is a great deal of work being done, both in the elucidation of impacts and linkages between impacts, and in the mapping of particular hazards onto hierarchies of management response. This paper contends that questions of resilience can be integrated into this work. But this paper further contends that "resilience" is such a powerful concept that it can be used in the analysis of fundamental strategy.

Jantsch (1975) makes this assessment of present planning and a possible solution:

> Instead of integrating physical and social planning with cultural design, we put our faith in what may be termed the "technological forward escape"... We attempt to drive out the dangers of efficiency... The alternative at the ecological level, as Holling and Goldberg (1971) point out, would be the replacement of an equilibrium-centred point of view by a boundary-oriented view... Such a framework "changes the emphasis from maximizing the probability of success to minimizing the chance of disaster... It shifts our interest from increased efficiency to the need for resilience".

This is primarily a polemical opposition. Lovins (1977), however, begins to create a different kind of opposition, not between "efficiency" and "resilience", but between "reliability" and "resilience". This is undeveloped, but in analysing the New York Blackout, Lovins makes this initial point:

> Billions of years of biological evolution, with resilience as the central theme, show that designs lacking in resilience were all "recalled by the Manufacturer". The Con Ed grid appears to be reliable but not resilient.

He then goes on to say:

> Our centralized electrical supply cannot discriminate well between users. Electricity for a water heater, which may be unaffected by a few hours interruption, must bear the cost of the extreme reliability required for a subway or an elevator.
>
> And the grid is all or nothing: It must be reliable because its failure is so catastrophic. If your oil-furnace breaks down, you can go next door. But if the grid fails, there is no next door.

This suggests something quite striking in its implications, if Lovins' analysis is linked to the concerns of this paper. It suggests that a case can be made for saying that modern society is following, at present, a strategy of reliability rather than a strategy of resilience. From what we have seen already, there is a further, almost inevitable, proposition that follows from the first: if society is following a strategy of reliability over one of resilience, does this not mean (a) that the one strategy is being developed at the expense of the other; and (b) that a strategy of reliability is ultimately much more dangerous than a strategy of resilience?

Let us expand upon this. If we are vulnerable - and we have agreed that we have many kinds of vulnerabilities - then there are, at least, two strategies of defence which do not involve active offense. We can rely on being able to shield ourselves from the blow; or we can rely on being able to absorb the blow. The first, shielding, concentrates on a continuous, reliable defence - reliability. The second, much less popular (for obvious reasons), relies on being able to bounce back from being battered or wounded - resilience. What is interesting to note is that failure of the first type of defence is catastrophic in a way unmatched by the second; since failure of the shield reveals a lack of absorptive capacity underneath.

This relates almost directly to one obvious concern referred to earlier in the introduction. There is a general concern that the modern, complex societies are becoming more vulnerable to attack. Part of this concern could be expressed as being an analysis that, by having to depend increasingly upon the kind of continuous uniform reliability exemplified by electrical power we are not only letting ourselves in for the possibility of damaging failure if there is one mistake, but this damage could be catastrophic because there is less and less resilience underneath. The example of the trucker's strike presents itself again: our dependence on an interlocked long-range supply system is in direct contrast to earlier localized small-scale self-sufficient town and village life (albeit at a lower standard of living). In the event of a modern city failing, there is little to "fall back upon", i.e. diminished resilience.

There seem to be any number of directions in which such an analysis could go: in the case of the Tokyo bombings at the end of the Second World War, also referred to earlier, it was mentioned that the citizens of Tokyo had to rely on the countryside for food. Does this imply that failure or reliability puts a premium on lower-level resilience, and that it is those resilient sectors which benefit from that failure (by being well "positioned")? One of the features of resilience is its regenerative power: can a reliable system, by contrast, not regenerate itself? If it can, does it do so by mimicking resilience; or by developing its own techniques; or by relying on reliabilities elsewhere? Can one safely move from resilience to reliability? How are each of these strategies affected by varying kinds of perturbations?

A way of tackling this series of questions, and of summarizing many of the points discussed in this paper, is to look at one sector in which "resilience" strategies *versus* "reliability" strategies are a central focus of attention. Climatic impact is one such sector, involving as it does energy and agriculture.

It has already been seen that climatic impact assessment is concerned with problems of sectorial "vulnerability" and "resilience"; and the last section of this paper will use that concern to draw together the main themes of the arguments presented, as well as propose some future research that this growing discipline might wish to incorporate in its preparation of modes and analyses of climatic impact relationships.

CLIMATIC IMPACT ASSESSMENT

Like the Ice Ages, the notion of a clear, measurable relationship between climate and society has undergone advances and retreats. That there is some relationship - even if only at the catastrophic level - has persisted; what has fluctuated has been the standard of acceptable measurement. A long tradition of climatic determinism stretching from Hippocrates to Ellsworth Huntington was only a few years ago held up as an exemplary model of a theory based on insufficient rigour and serious cultural bias. Yet, just as Quaternary research has brought the description of the effects of ice ages on human prehistory within tantalizing reach, so the developing sophistication of climatic modelling and social science techniques has prompted a re-appraisal of "climatic determinism".

The seductiveness of the possibility of a working theory, combined with the quantities of data becoming available, have provoked a large amount of interest in climatic impact assessment. Much of the interest has been centred in the popular press and popular non-fiction, but the importance of the subject has recently been confirmed in the declarations of the WMO Conference of February 1979. In Canada, the continuing series of user's conferences providing input into the proposed Canadian Climate Program is a mark of national concern.

A number of factors has led to this belief (or hope) in being able to model, predict, assess, or otherwise analyse the impacts of climate on society. Some were hinted at in the opening paragraph, but it is worth clearly outlining these and others below:

(i) The increasing sophistication of climatological data gathering both for the present and past climates;

(ii) The rise of neo-evolutionary theory (or cultural ecology);

(iii) The development of social assessment techniques (exemplified by the CIAP studies in 1974-1975 in the U.S.A.);

(iv) Concern over climatic impact on underdeveloped nations.

Assessing possible climatic changes or the frequency of climatic fluctuations demands a background of historical data which can match the increasing sophistication of twentieth century instrumental records. Climate change in historical times has been the subject of a great deal of recent work (Lamb 1966; 1972; 1975; 1977) both attempting to wring as much information as possible out of scanty historical records before our own day (Ladurie 1971) and attempting to ascribe to climatic change some of the broad shifts in human history (Bryson and Murray 1977). The "Little Ice Age" of approximately 1400-1700, for example, has now found its place in standard histories of the period (Eddy 1977; Parker 1979). Palaeobotany, pollen analysis, changes in lake levels, glaciers, and tree lines, as well as more ancient geological evidence are all pushing back the time scale of discussable phenomena (Gribben and Lamb 1978). In particular, evidence for the existence of a "climatic optimum" culminating about 4,000 B.C. has become part of the background to the "neo-evolutionary" debate over the origins of civilizations.

This theory, most associated with the names of American anthropologists such as Steward, Service, and Sahlins, has concerned itself with the broad explanations of the rise of civilizations through definable stages of evolution. Two events of theoretical importance are: first, a world-wide shift from hunter/gatherer societies to sedentary agricultural civilizations; and, second, the relationship between irrigation and centralized government (the "hydraulic" concept). Both of these

events have commandeered climatic change as an element in hypotheses of explanation. As an example of the first, Harris (1977) suggested that the shift from a reasonably benevolent way of life hunting/gathering has been shown to be a more than acceptable existence strategy as long as population density is low (Sahlins 1972; Lee 1968; 1969) - to the agricultural mode, depended on an ecological catastrophe triggered by a combination of glacial retreat and increasing human predation on the Pleistocene megafauna left behind. Cohen (1977) has criticized this explanation, offering population pressure as a more direct cause of sedentism, but without denying climatic influences.

The second, the "hydraulic" concept, first proposed by Wittfogel in 1955, linked the rise of centralized government in Sumeria and elsewhere to the need for large-scale irrigation projects. Criticized by Adams (1965), especially for insufficient attention to social determinants, the concept nevertheless has brought into the foreground the possible complex interrelationships among climatic, social, and technical factors in the explanation of cultural change. Recent excavations (Oates 1977; Moore 1979) have underscored this complexity, but have occasionally sought to embed the history of settlements in a definite climatic sequence (Moore 1979).

The complexity of the interaction between climate and proto-historical societies is due as much to the paucity of available information as to anything else; the precise opposite is the case in studying the interaction between climate and modern societies. Techniques for describing decision making under conditions of uncertainty (Lindblom 1959; Newell and Simon 1972; Tversky and Kahneman 1974) as well as forecasting the results of decisions have come into use (Finsterbusch and Wolf 1977). This has promoted and been promoted by the realization that climate may be a "resource" along with many others (Maunder 1970; Taylor 1974), and may be part of hitherto externalized costs or benefits. The debates over the SST, (CIAP 1975), possible impact of CO_2 warming, ozone-layer depletion, and climate modification by deliberate policy have all been part of a sharpening of the tools of analysis. At the same time, there has been a shift from benefit/cost analysis through benefit/risk analysis towards environmental risk management (O'Riordan 1979 has a differing trajectory) as more and more of the intangibles and "second-order" effects become pertinent to realistic appraisal.

Adding its impetus to the theoretical developments outlined above, there has been a steadily growing acknowledgement of the importance of climatic stability to the modern world. While the climatic trends of the last thirty years have caused a slow but significant re-appraisal of the normality of the largely benevolent weather of the previous half-century, it was the combined stresses of the climate-related disasters in 1972 and 1973 around the globe which pressed the point home. The drought in the Sahel, the failure of the Peruvian anchovy harvest, the bad Soviet harvest and the subsequent Soviet purchase of massive amounts of grain on international markets - all these served to direct attention towards the possibility of mitigation of climatic adversity through better forecasting or through a better understanding of the social forces at work.

One attempt to slice through this vast array of numerous agendas, and to find some common or generalizable characteristics of climate-society interactions, has been the recent Clark University Climate and Society Research Group's project on the effects of climatic fluctuations on human populations, a project briefly referred to already. By comparing the drought in the Sahel, the history of the Tigris-Euphrates valley, and the series of droughts in the American Great Plains, this group hoped to generate some useful hypotheses. They proposed two, which were:

(i) Persistent and adaptive societies, through their technology and social change, *lessen* the impacts of recurrent climate fluctuations of similar magnitude upon the resident populations and indirectly on the whole society; but

(ii) this success in insulating a livelihood system from recurrent climatic fluctuations comes as a result of increasingly elaborated technical and social systems. These, in turn, increase the vulnerability to catastrophe from natural and social perturbations of rare frequency (Climate and Society Research Group 1979).

In the case of the Sahelian drought, there were two related hypothesis, which we have had occasion to note before, one suggesting that modernization was "lessening" the impact of drought, and one suggesting that modernization was "worsening" the impact of drought. Comparing the droughts of the period 1910-1914 to 1968-1974, the researchers had great difficulty in deciding what constituted "lessening" or "worsening". The evidence suggested that morbidity had gone down in the second of the two fairly comparably drought periods, which was a form of lessening; and that greater stress had been put on different sectors, e.g. nomadic peoples, which was a form of worsening. But, perhaps most important, the second drought period had produced a "relative worsening", a result which can only be described as the destruction of the resilience of the underlying traditional social system. This was tied into

> the growing failure of subsistence systems to provide the livelihood of those dependent on it, and the gradual monetarisation of all exchanges.

The Sahelian people, through the modern drought, were being compelled to shift out of their low-level resilience strategies into what this paper would call the reliability strategies of a market economy. The danger is not in this drought, but in what this drought means for the "positioning" of the Sahel in the face of the next drought.

The Tigris-Euphrates case was inconclusive, but in a different way than the Sahelian study, since the sheer difficulty of integrating the different archeological, social, technological, and historical data into a 6,000 year story defeated most speculation. From material presented, it is possible to surmise that political and technical integration were important to the sharp increases in population at various times, and that this integration either took advantage of, or was promoted by improved climatic conditions.

The case of the Great Plains and the analysis of drought linkages has already been mentioned, but the conclusions are worth describing. First, the spread of effects outside the localized area to national and even global effects in the most recent droughts in the Great Plains is evident, and increasing. Second, this has resulted in a form of "lessening" of impact locally which is not due to drought-wheat yield relationships (at least from the evidence), but to the shift of response to impact onto the greater social system.

At the time of writing, these three case studies are still in progress. The establishment of a clear relationship between these cases and the major hypotheses of the overall study is of great importance, if the general outlines of this paper are accepted, since the hypotheses relate directly to our present concerns. A few additional remarks may therefore not be out of place.

In the case of the droughts on the Great Plains, the spread of the impacts of the drought outside the locally vulnerable area is due to both a spreading out of the area served by the vulnerable area, and by the steady transformation of the impacts into impacts convertible into monetary impacts. If the second hypothesis of the Clark Group is correct, this is part and parcel of the increasing success in insulating the livelihood system from recurrent climatic fluctuations. Through the use of "elaborated technical and social systems", this insulation, this dampening of fluctuations is essentially based on the reliability of the market system and the socio-political system, which in turn need to support the constant reliable functioning of the vast and now interdependent food production industries. Each of these systems supports the other in trying to ensure a stable growth pattern in modern society. This is achieved by translating vulnerabilities and impacts into monetary equivalents, and then retranslating them back into goods, services, insurance, loans, etc. Climatic fluctuations or extreme climatic events, which can be an independent variable in this system of mutual reliability, are - except perhaps for death - now "dollar events". This must be emphasized, because it was not always the case, or at least to this extent:

> In the United States, the Boston snow storm of February 1978 is estimated to have cost regional commerce $1 billion dollars. An equivalent storm a century earlier would have had little impact; over the century, society had been transformed (McKay 1981).

That is, the storm would have had little regional economic impact since the impacts would, instead, have been localized suffering.

The same holds true for agriculture:

> Although agriculture is now well conditioned against climates that produced starvation in pioneer days, neither the fluctuations nor the related losses have disappeared... A precocious but cool spring and a wet mid-summer in 1976 led to crop insurance payments (in Ontario) exceeding $8 million dollars... The individual sectors will continue to be affected but by insurance and assistance agriculture appears to be durable (McKay 1981).

Crises in mortality have been replaced by crises in liquidity.

In this sense, the economic system (supported by the social and political systems) has become the absorber and defence of first resort. This is one reason why international comparison of hazard impacts is occasionally easy, but often difficult, since, as has been noted, First World losses from natural hazards are primarily "property"-oriented while Third World losses are often more "people"-oriented (Kates 1980).

One further step can be taken. A farmer, for example, in the First World, attempting to minimize the impact of climatic hazards has, at the very lowest level, a certain common resilience inherent in the fact that he is a human being, that he can commandeer certain resources by ownership or force, and can thereby withstand certain "ups and downs" common to all. In pioneer days, this would have been a farmer's primary - and only - strategy for survival. With the development of a more complex society, including the establishment of a stable market economy, the farmer begins to be able to create and use a surplus which he can invest in buffering himself against such things as the vagaries of climate. He can either invest in ways to increase his ability to withstand the "ups and downs" himself - by mixed farming, by livestock acquisitions as alternative food storage, etc. - or he can invest in a more widely spread interdependence which spreads the risk and reduces the perturbations of the social environment. Of course, this choice can often be forced by the very nature of social developments.

In any case, the First World farmer is able to carry on both a low-level strategy of resilience - getting by through the ups and downs in the ways farmers always have - and a new high-level reliability strategy which ensures that he will get a regular price and regular buyers for his crops in exchange for regular supplies. The Canadian Wheat Board is a symbol of the process. Reliability of supply through emphasis on one-crop farming, high technology and fertilizer inputs, is matched and reinforced by regularization of demand through the dampening down of economic fluctuations.

Farming is only one example of this interactive process, which is taking place in forestry, energy, water, and other sectors of modern society. The critical question of all these cases then becomes: if there is a catastrophic, even though infrequent, event which wounds or destroys this interdependence, is there enough residual resilience for the society to "weather the storm"?

Let us also look at the case of the Third World. The poor and traditional farmer, though he appears to be inefficient, is, in fact, following a resilience strategy (like that of the First World pioneer) which minimizes uncertainty in the face of risk (see essays by White 1974; esp. Kirkby) through the use of what few resources are available. Except possibly at a community level, there is little surplus to get the elements of the society as a whole, "over the hump" into the kind of market interdependence and monetary support available to the First World farmer.

So, in a replay of the concerns expressed by natural hazards researchers, it can be seen that when the shift in strategy is made from local resilience to general reliability (either by choice, as in the rapidly developing world, or by necessity, as in the Sahel) the society partaking in that shift is exceptionally vulnerable in the no-man's land between strategies. And here there is a point of comparison between First and Third World: when catastrophe strikes the reliability system of the First World, it can either be reconstructed, or the members of the system can revert to a resilience strategy (unless, of course, reliability inhibits underlying resilience); when catastrophe strikes the proto-reliability system of the Third World, the members of that system have no choice but to fall back on traditional resilience, *which may not be there any more* in the disruption caused by the transition.

One last connection can be made. As the drought in the Sahel seemed to show, one of the changes in a system undergoing transition from resilience to reliability is that different sectors become more vulnerable than others, in this case, the nomadic population. While this is not the place to go into the characteristics of the transition, it can be stated that this is what appears to be happening in the larger case of the First World over against the Third World. That is, the First World's strategy of reliability shifts vulnerability more and more onto the shoulders of those who do not belong to this strategy, or who are trying to belong to this strategy. This is obviously another version of the argument of under-development of the Third World by the First World; but here the emphasis is not on economic conflicts *per se*, but on the conflict between risk strategies. It explains, for instance, the difficulty of establishing a world-wide food reserve; since to say

> Clearly there are two sides to the food problem: one is to increase production; the second is to create purchasing power among the hungry (Wortmann and Cummings 1978)

is to ignore the way in which these are, for the time being, mutually incompatible goals. The First World farmer has no incentive to support stockpiles of grain, except in those periods when a gross surplus may invite such a stockpile to support prices, because the stockpile would depress prices; and would, of course, not be for him except in time of immeasurable catastrophe. And for the Third World farmer, free available grain destroys the possibility of purchasing power on his terms; and, at the very least, pushes him in the direction he may least want to go - that is, from traditional resilience into the international market place. At the same time, the seemingly inexorable nature of the First World reliability strategies - with their benefits and costs - is pushing high-technology monocultures forward which are undermining the traditional farmer anyway. What is happening is that the creation of purchasing power is being more and more closely tied into the reliability strategies of regularized supply and demand, so that in order to earn purchasing power, the farmer has to abandon resilience (in the worst case) for the other strategy. And, ultimately, there is a final twist to the knife: in the event of world-wide stresses (such as occurred in the climatic anomalies of 1972-1974), the standard supplies of food, oil, and other commodities are spoken for, and the surplus (stockpiled) supplies become the back-up or "buffering" stocks - all of which are portioned out in the reliable marketplace. For the Third World, however, this "buffering" capacity is not a second-rank back-up; it is the only available back-up. And yet, as has been said, in a world-wide shortage this means that not only are they pushed to the back of the bread-line; they cannot even afford to buy the bread.

CONCLUSIONS

As one hopes the last section has shown, there is a lot of valuable work that is being done, and that can be done in analysing the relationship between climatic fluctuations and social systems both at the local and at the international level. This paper contends that the best way of proceeding is by giving consideration to the strategies being used by various societies to protect themselves from uncertainties of many types including climatic uncertainties, with special reference to the ways in which these societies seek to reduce vulnerabilities by enhancing reliabilities or resiliencies. This is directly relevant to the impact hypotheses already produced by some researchers, and can serve as a connecting link between case studies in progress and those in the works.

Specifically, country-by-country research might focus on some of the following questions and issues:

i. Can the hypothesis that modern societies are choosing reliability over resilience be supported?

ii. Is this strategy undermining the resilience of modern society?

iii. What would the necessary reversion from reliability to resilience in time of need look like?

iv. What elements of a modern society are most easily translatable from one strategy to the other in time of need? Would they be worth enhancing?

v. Is there a core of resilience in modern societies; and is it comparable to historical or traditional equivalents?

vi. Can priorities in resilience, especially in the provision of the possibility of continued adaptation or response, be identified?

vii. Is the reliability strategy of the First World undermining a different strategy in the Third?

viii. Can resilience in the Third World be supported in the period of transition, or in time of disaster, without undermining it?

ix. In the debate over such questions as agricultural diversity or energy supply, is it possible to assert "resilience" over "reliability"?

Many of these questions and issues could be evaluated under the aegis of the social impacts section of the World Climate Program or in national Programs. Case studies in energy supply and demand, the use of historical records to document the postulated transition from "resilience" to "reliability", and the evaluation of a wide range of strategies now in force in many sectors could provide a wealth of information for the understanding of this question. It also appears to be true that a number of decisions, some made, some pending, in such areas as strategic supplies of various commodities or alternative sources of energy, may be intimately related (even if unknowingly) to the processes we have been outlining in this paper. Assessments of these decisions could also be of assistance.

In the course of this long and diverse review of various theories of possible system collapse, a collection of models, hypotheses, and analogies has been provided, all attesting (in various ways) to the basic human concern for individual and social survival manifested in all places and at all times. We have seen that, as the social system and its interaction with the natural world became more and more complex (and came to be perceived as such) and more and more difficult to intuit or predict, so, in turn, the models have become more and more aware of these complex interactions and processes. Borrowings from the latest technology or the latest possibly relevant analogy have been made for the purposes of understanding ever since Plato used the loom and the potter's wheel to describe the warp and woof and turning of the universe. We have also seen that most of these models are inseparable from moral questions, whether they be prescriptive or descriptive models.

One of the problems that fuels the fear that we are now more "vulnerable" than ever, is the suspicion that our models and analogies, as they now are, are inadequate both to describe the physical interactions of a social system and to assess the moral "glue" that makes us believe that the system is worth understanding at all. In the end, it may be that this is what we are really asking for: that what we need above all are models - of whatever kind - that are the least vulnerable and most resilient we can find.

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